RECORDS

OF

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CONTENTS.

PART 1.

PART 2.

PART 3.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1887. **[February.**

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA, AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1886.

SOUTH INDIA. *Mr. Foote.*

For the past three field seasons Mr. Foote has had the Madras Presidency all to himself. This came about in the course of a perfectly natural selection in the distribution of a limited staff according to the urgency of demand, whether practical or scientific. In the early days of the Survey the whole staff was for several successive years engaged upon the coal-fields, and ever since continuously several geologists have been so engaged, but Madras is not favoured in that line, the Gondwána coal-measures being only found in a part of the Godavari district. For other reasons, however, Madras very early received our best attention. In taking up a new country the rational method of geological enquiry was to get hold of such formations as offered, through their fossils, the means of establishing correlations with known rocks, and from those fixed horizons to obtain indications as to the ages of contiguous deposits. In this way the best part of the Survey staff were, at the beginning, for several years engaged in Madras; and the proportion was fairly kept up until nothing was left but the immense residuum of fundamental gneiss and the oldest schists that locally accompany it; while other parts of India offered more promising fields of research for the final solution of the total complex of formations in Peninsular India. This accounts satisfactorily for Mr. Foote's recent isolation; but the local authorities only recognised the isolation, and remonstrated against it, so it has been decided to add Mr. Fedden to the Madras party of the Survey. Before going on furlough, Mr. Fedden had finished his survey of Kathiawar, and I had intended him to take up new ground in the Rewa Kanta districts of Guzerat, but he has now begun work on the gneissic rocks of Vizagapatam. Results are very slowly acquired in rocks that are so obscure and so extended. Mr. Foote during last season mapped a considerable area in extension of his previous work in Bellary, both of

gneiss and of his Dharwar schistose series. He suggests a probable correspondence of a large part of the gneiss with that of Bundelkhand, long ago distinguished as older than the prevailing gneiss of Bengal. It was then also shown that the gneiss east of Chaibassa, in Singhbhum, is probably of the same age as that of Bundelkhand (Manual, p. 21).

Mr. Foote resumed his survey in Bellary at the beginning of the current season, but he has since been deputed to report on some gold-fields in Mysore, at the solicitation of the local authorities. Although these interruptions to our regular work are somewhat perplexing, it is right that the best knowledge and experience should be made available for the furtherance of practical objects.

THE KARNUL CAVES.

We have now published in admirable form by Mr. Lydekker in the Palæontologia Indica the detailed description of the fauna of the Karnul caves, discovered and so carefully explored by Mr. Foote and his son, Lieutenant H. Foote, R.A. If the results were disappointing in respect of what was most hoped for—prehistoric human relics (though upon this point I believe Mr. Foote has still a word to say regarding certain cut bones)—the general results are of considerable interest. As to the age of the fauna, Mr. Lydekker remarks:—"The comparatively large number of species either totally extinct, or which are not now found living in India, renders it probable that the age of a considerable part of the Karnul cave deposits is not newer than pleistocene; and the fauna, as being almost certainly more recent than that of the Narbada beds, may be provisionally assigned to the later part of that period." The numerous affinities with African types is a feature previously noted regarding the Tertiary (Siwalik) fauna of India.

CHHATTISGARH.
Dr. King.
Mr. Bose.
Mr. Hira Lall.

Dr. King's regular work in the hills west of the Chhattisgarh plains was necessarily much interrupted by his having to superintend the coal explorations in the fields far to the east. The results of those trials were published in the Records for November, and it has to be regretted that the Rampur field, which is the one crossed by the new line of railway, does not promise a fair supply of fuel. The trials were all by borings, but the samples of each seam were taken very carefully foot by foot, and separately assayed. The amount of ash in almost every case was prohibitively high, from 30 to 50 per cent. In only one seam, in the Baisandar valley, the average was 21 per cent. of ash, the 5th, 6th, and 7th feet giving only 6·52, 12·08, and 18·68. Thus it may yet be possible to get small local supplies from some of these seams, and no doubt this will be attempted by shafts when the demand comes to be pressing. Meanwhile the exploration is being carried on in the nearest ground to the north, in the Mánd valley. In the remote hill country, far to the north of Korba, a large new coal-field was traced out by Sub-Assistant Hira Lall: it is the western extension of the measures noticed some years ago by Mr. Ball at their eastern extremity as the Lakanpur field.

The relations of the rocks forming the plains of Raipur to those underlying them on the west is still under examination. Dr. King describes the bottom sandstone of the Raipur series (? Lower-Vindhyan) as resting with partial unconformity on shaly beds of the Chilpi series—general parallelism of dip at low angles with local overlap and discordance—a like relation to that described by him between the Karnul and Kadapa formations, or even between the separate groups of the Kadapa

series. It seems as if the chief difficulty would be with the lower members of the Chilpi series in connection with igneous and schistose rocks. Dr. King reported upon Mr. Bose's work as still exhibiting the want of observation and study that had been found fault with in previous seasons; I may however add, that since going to the field this season Dr. King has written less unfavourably of Mr. Bose. I only hope he has not been beguiled.

SOUTH REWAH. *Mr. Hughes.*

Mr. Hughes' deputation in charge of the Umeria colliery did not terminate till the end of December (1885), and for the rest of the season he was engaged in examining the rocks above the coal-measures, and succeeded in finding some new localities for fossils in them. At a few miles to the west, on the Son-Máhánadi, the Jabalpur beds (top Gondwána) are typically represented, and the problem is to make out some distinctions in the variable thickness of sandstones shales and clays between those beds and the coal-measures, representing what in other fields constitute quite two-thirds of the Gondwána system. The most marked stratigraphical boundary in the whole basin is that just above the coal-measures, as was formerly observed in the Warda-Godavari basin; yet in neither case does it seem to involve a correspondingly marked change in the fossils, for a considerable thickness of beds above that boundary still contain distinctively lower Gondwána forms. Mr. Hughes has already seen a great deal of those upper rocks, having been at work in Rewah since 1879; and in the north-central portion of the basin he hit upon some fossils marking distinctly the Kota Maleri and Denwa horizon; so it is altogether very disappointing that he has not yet offered any clue to an interpretation of the stratigraphy where it presents any difficulty. On this account, lest we should hopelessly lose any benefit from the extensive acquaintance Mr. Hughes should have acquired of that ground, it was with much reluctance that I recently consented to his deputation for the present field season to the Nizam's territories, to conduct exploration for minerals; but practical objects must, I suppose, claim precedence.

THE CHHINDWARA COAL-FIELDS. *Mr. Jones.*

During the past season Mr. Jones completed the survey of the southern coal-fields of the Satpura Gondwána basin. There are altogether eleven separate areas where the coal-measures group is exposed, seven of them being in the Chhindwara district. The four adjoining areas in the Betul district were mapped and described some years ago (Rec., VIII, 1875). The intended exploration of the seams by trial borings in connection with the survey not having been carried out, the information regarding the prospects of the field is little better than before, the principal outcrops having been already reported on long ago. Mr. Jones has now given a full account of all the exposures and defined the limits within which there is any chance of finding coal. On the whole, the quality of the coal, so far as it can be ascertained from outcrop samples, is not very encouraging. The report and maps are now at press. As a geological study of a very interesting region, Mr. Jones' report is disappointing, through defect of critical observation and discussion on the ground, for it is futile to expect to solve stratigraphical puzzles by the colligation of field notes; the problems must be stated, and to a great extent solved on the spot; the description of them is then a simple matter. The failure to find a single recognizable fossil during two seasons' work on these coal-measures is similarly unsatisfactory.

This piece of work corresponds to Mr. Hughes' description of the southern coal-fields of the Rewa Gondwána basin; and here, as there, the chief puzzle remains—to put in order the main mass of Gondwána strata above the coal-measures. A preliminary attempt at this was made in 1873 (Memoirs, Vol. X).

RAJPUTANA.
Mr. Hacket.

For a great part of last season Mr. Hacket was engaged in endeavouring to clear up the perplexities of the Arvali rocks by a further study of them on their eastern margin, about Chitor and Neemuch, where they are in contact with an archæan gneiss. In this ground in 1881, as was noticed in the annual report for that year (Rec., XV., p. 3), Mr. Hacket made out that the sandstone of Mundsaur, which had originally been taken to be Vindhyan, as occurring close to these rocks and quite like them petrologically, was really identifiable with the highly metamorphic Delhi quartzite (see Rec., XVII, 103) so extensively exposed in the north-east of the Arvali region. This implied a wide distinction of this member from the schists with which it is generally associated throughout the region, and of course a complete separation from the Vindhyans, which are elsewhere quite unaffected in immediate proximity with the Arvali slates. Mr. Hacket now extends this identification so as to include the Arvali schists: the sandy calcareous conglomerate resting on the gneiss near Dhaulapani (20 miles south-west of Neemuch) and containing pebbles of that rock, passes below the limestone and shales that underlie the Mundsaur sandstone, and these also are traceable to the north continuous with the slates, schists, and limestones of the Arvali series. Thus the partial break in that series, as established in 1881, is a good deal modified, and we now seem to have representatives of the whole metamorphic series of the Arvalis (so far as at present made out) in unaltered original contact with an archæan gneiss of the peninsular area, as if sheltered in a bay of that most ancient land from the contortion and metamorphism that took full effect upon the same deposits in the main area to the westward. The western boundary of this old gneiss is very obscure, owing to the changed condition that rapidly supervenes in the newer rocks on that side, where they are extensively transformed into a schistose gneiss. In confirmation of this distinction of two gneissic formations, Mr. Hacket describes the occurrence of boulders of gneiss in the schistose gneiss at the village of Mandkhola (Lon. 74°-34′, Lat. 24°-7′), but the observation needs critical petrological confirmation. The re-connexion of the Delhi quartzite with the Arvali series is more in harmony with the fact of their association over so large an area; but Mr. Hacket considers that there is probably some unconformity, for the massive quartzite is locally in contact with different rocks of the underlying series; this, however, might be due to faulting where the strata are so greatly disturbed. The gradual change from the quartz veins so abundant in the slates of the eastern part of the region (as east of Deoli) to the granite veins that similarly pervade the schists of the central zone, is a noteworthy feature. On the other hand, Mr. Hacket notices patches of comparatively unaltered slates within the area of the schistose gneiss, as close to the east of Oodeypore, and again on the west side of the Arvali range east of Mera (close to the north of Abu); but these may only be, as Mr. Hacket suggests, freaks of partial metamorphic influence within the same rock series.

The stratigraphical relation now brought forward of the Arvali series to the old

gneiss, brings it into neater comparison with the Bijawar (transition) series of the Peninsula which rests in like manner on the south margin of the Bundelkhand gneiss. The characteristic breccias of the Bijawar area and the Narbada valley are not represented in the Neemuch sections, but the absence of such peculiar rocks may not signify, so the wide correlation may be provisionally accepted. The other pre-Vindhyan formation, the Gwalior series, resting on the northern margin of the Bundelkhand gneiss and not specifically identifiable with the Bijawars but having some points of affinity with the lower-Vindhyan and the Kadapa, was found characteristically represented in the Arvali area at Hindown, and subsequently Mr. Hacket made it out to be a member of his Arvali series (Rec., XII, p. 24). We thus seem to have in this region, on the north-west border of the Peninsula, an extensive exhibition of a great system of very ancient rocks that occur locally in various parts of the peninsular massif.

We are still however very much in the dark upon the details of the relations and homotaxis of this immense sequence of formations (including the Vindhyans), all having as yet proved azoic. No unconformable break could be more marked than that of the typical lower-Vindhyans and the Bijawars throughout the Son valley; yet here in the Neemuch district we seem to have members of the older series that were originally by petrological characters and stratigraphy placed with the adjoining upper-Vindhyans. Thus there is unlimited room for the discovery of 'mistakes,' than which nothing is more gratifying to the average human being; so the present apparent anomalies of the situation are here broadly indicated to stimulate the ardour of future explorers.

Mr. Oldham.

Mr. Hacket's work in Rajputana has been confined to the older rocks, the Arvalis and the Vindhyans, to the west of which, in the more or less desert country of Jesalmer, the existence of fossiliferous limestones has been known for many years. Mr. Blanford made a traverse of that ground in 1876, from Jodhpur to Rohri on the Indus, and noted a succession of jurassic strata more or less corresponding to those described in Cutch, and of course they are also the marine representatives of some of the Gondwána system. They are surmounted by tertiary (nummulitic) limestones and clays. During last season Mr. Oldham was deputed to explore the northern extension of those rocks towards Bikanir. He found that at about 25 miles north of Jesalmer the nummulitic strata sweep round eastwards passing northwards under the desert of Bikanir. But the most interesting of his observations was that the boulder rock of Pokaran, which had previously been taken to be Vindhyan (although recognized as of glacial origin), must really be the Talchir boulder bed, occurring as that bed so constantly does upon a denuded surface of very ancient peninsular rocks, and forming by position the base of the sequence of mesozoic strata occurring at some distance to the west. As the Talchir group forms all over India the base of the Gondwána coal-measures, Mr. Oldham suggested that there was room in the covered ground between the boulder bed and the marine jurassics for a possible occurrence of coal-measures, with coal. The fact of there being a continuous sequence of marine strata on this horizon in the Salt-range is not in favour of the conjecture, but neither does it forbid it. Mr. Oldham was not very sanguine of success, but in view of the great want of coal in that quarter of India the question was worth looking into. This is now being done; and the latest information is not encouraging: in a

letter dated 1st January Mr. Oldham informs me that he has in some places found upper Gondwánas overlapping unconformably on the Talchirs.

Mr. Kishen Singh.

Sub-Assistant Kishen Singh has completed the work he has been engaged on for some seasons, to map the upper-Vindhyans of the Chambal basin. The ground was very imperfectly known, from a single traverse made some years ago by Mr. Hacket to fix approximately the northern boundary of the trap of the Malwa plateau. The continuous survey has brought out some unimportant corrections. The sandstone of Jhalra Patan which had been taken to be Rewah sandstone (upper-Vindhyan) is shown by Kishen Singh to pass beneath the shales and limestones that underlie the Kaimur sandstone and is so proved to be lower-Vindhyan. None of the peculiar lower-Vindhyan beds, such as the Tirhowan breccia of the Bundelkhand area, or the porcellanic and trappoid beds of the Son valley, have been observed in Malwa. Kishen Singh has now been transferred to map the boundary of the Deccan trap in the Mandla and Seoni districts.

ASSAM.
Mr. La Touche.

Mr. La Touche made good progress with his work in the Garo Hills during the past season. Although the structural features are not obscure, progress is greatly impeded by the dense vegetation and the scarcity of fossils in the sequence of tertiary rocks above the nummulitic horizon. Mr. La Touche's progress report is published in the current number of the Records.

HIMALAYAN REGION.
Mr. Middlemiss.

During this year again Mr. Middlemiss has been alone in the Himalayan region, and he has done excellent work. His genuine enthusiasm and thoroughness are most refreshing, his real aim being, not to make a display, but to understand. The account of his work is given in the current number of the Records; it was fully ready for publication in October last, but had to be deferred for more urgent though less important work. His ingenuous exposition, and illustration from a local instance, of the 'folded flexure' (to use the older and neater term originally given by Professor H. D. Rogers)[1] and its attendant 'reversed faulting,' and of their function in the formation of 'true mountains,' will be instructive to many. Mr. Middlemiss' paper describes a very complete geological feature, about 45 miles in length, immediately east of the Ganges and at the edge of the Lower-Himalayan region, just inside the fringing zone of Sub-Himalayan rocks. It is in the main a long ellipse of crystalline schists surrounded by a narrow fringe of newer strata. To mark how backward we still are (malgré nous) even in the superficial knowledge of large tracts of country, it has to be confessed that this description came as a surprise. In previous notices of this region it has been stated that although the Lower Himalaya begin with a great spur of crystalline schists and gneiss reaching to within 7 miles of the Sub-Himalayan zone between the Beas and the Sutlej, the predominance of crystalline rocks in it comes on in eastern Kumaun, on the frontier of Nepal; but we now see those rocks already established in force close to the east of the Ganges and at the very edge of the region.

Mr. Middlemiss now puts us in possession of a more or less detailed description of a third detached section of the Lower Himalaya. This apparent want of system and continuity of work has already been duly explained by the advantage of taking up ground of which fair maps are available, and this only occurs in the purely British

[1] Memoirs, Vol. III, pt. 2, pp. 194-5.

districts. But indeed there may be some compensating advantage in these independent studies of adjoining areas, the adjustment of discrepancies being perhaps more likely to give true results than might have been attained in any endeavour to carry out over a large area a scale made out in a part of it. In the present case the discrepancies are considerable, and it will be well to exhibit them in juxtaposition. The first of the sections referred to is that in the Simla area at the west end of the Lower Himalayan region, where there is the widest display of unaltered rocks. The work there was mine (1859-62),[1] and it has least claim to consideration, for it made no pretence to be a survey; the map was a poor one, on a small scale, and the observations were made from cursory traverses of the ground in connexion with a more careful study of the Sub-Himalayan zone, which was really the work in hand, the area covered being evidence to the point. The second area, 30 miles east of Simla, was by Mr. Oldham (1883)[2] with the new map of Jaunsar. The third area is 30 miles further east, in Garhwal, by Mr. Middlemiss, now published. I have placed the groupings below in parallel columns, indicating any suggested correlations. In the first column I give Stoliczka's conjectured affiliation of the Simla sequence (from his own observation) with that in Spiti.

Spiti.	Simla.	Jaunsar.	Garhwal.
Lilang	Krol (limestone).		
(upper trias).	Infra-Krol.		Tál (mesozoic).
	Quartzite.		Massive limestone.
Kuling	Carbonaceous shales.	Bawar.	
(carboniferous).		Mandhali.	
		Deoban (limestone).	
		Chakrata.	Purple slates.
		Limestones and slates.	
Muth	Blaini		
(upper silurian).		Volcanic beds.	Volcanic breccia.
Upper Bhabeh	Simla slates.		
(lower silurian).			Schists.

The chief discrepancy is between the sequences of Simla and Jaunsar, Mr. Oldham asserting provisionally that the rocks in either have no representative in the other (*supra*, xviii, p. 4). The horizons he does suggest are indicated in the table: that the Bawar represents part of the infra-Krol; that the Deoban limestone is much older than the Krol limestone (they had previously been supposed the same); that the Blaini is newer than the Lower Chakrata (volcanic beds). Mr. Middlemiss refrains from correlations, not even saying whether his massive limestone may be Krol or Deoban, with the apparent notion that all may yet prove to be one and the same. It would be futile to speculate upon identifications that will in due course be settled by actual survey, but there is one theoretical question upon which I wish to offer a reflection. That the Simla section does not represent a conformable sequence, is a statement I should never have disputed under any strict meaning of the term 'conformable'; but among the several inferences I ventured to put forward one had appeared to me on the ground as very remarkable—the parallelism of stratification between the newest and the oldest formations. The most striking instance

[1] Memoirs, Vol. III, pt. 2.
[2] Records, Vol. XVI, p. 193, with subsequent corrections, Vol. XVIII, p. 4.

given was that of the nummulitic with the infra-Krol beds at Subathu, where throughout a considerable synclinal fold a characteristic bottom bed of the Subathu group coincides with the bedding of the underlying slaty shales. The denudation-unconformity here involved is, of course, prodigious; but the agreement in stratification is only the more remarkable, and it is constant at this horizon throughout this zone of extreme contortion to the north-west, and is still preserved, with little disturbance, in the Salt-range. The interpretation I ventured to put upon this fact seemed one of considerable importance in the history of mountain formation—that in this zone at least little or none of the contortion peculiar to mountain structure had yet affected the old slates at the beginning of the nummulitic age. It was, and is, inconceivable to me that strata which were originally highly discordant could by any play of subsequent contorting action be brought into parallel contact, even exceptionally, much less throughout a great area. A similar parallelism seemed to me to obtain throughout the Simla section. My successors have treated this suggestion with silent contempt; extreme and wholesale unconformities (meaning of course the original relation) have been freely introduced. I have myself indicated a fact of mountain-growth (Manual, p. 550) that would at least locally reconcile such discrepancies—how complete conformity and utter discordance may grow together side by side—but for actual original contact-sections the inference I drew still seems to me rationally binding, and I would call upon my successors to apply it or refute it.

TRANS-FRONTIER.
Mr. Griesbach.
Dr. Giles.

Mr. Griesbach reached India on the 1st November with the Afghan Boundary Commission, not much the worse for the two years' journeyings. His notes on Turkistán appeared in the Records for November, and notice of his return traverse from the Oxus to India is published in the current number. The former was a prolongation eastwards on the strike of the formations previously noticed, where they form the Tirband-i-Turkistán, the principal north-western flanking range of the Afghan mountains. The upper cretaceous limestone assumes quite a predominant place, resting unconformably on the older jurassic and triassic strata, which only appear where exposed in the axes of denuded anticlinals. The lower flanking hills expose a great thickness of tertiary strata dipping at high angles beneath the deposits forming the plains of Turkistán. In connexion with the latter Mr. Griesbach notices an apparent continuation of the same elevatory action now going on in the plains south of the Oxus, attributed to a flexure in process of protrusion by lateral pressure. The evidence for the fact itself, as thus explicable, is only indirect, and perhaps needs confirmation by actual levelling. At the eastern end of the Tirband range better sections were obtained of the older rocks, in the lower members of which some extensive coal-measures were discovered; and Mr. Griesbach reports the important fact that the bottom conglomeratic beds of the series (presumed to be Talchirs) as observed near Herat are found in the Bamian sections associated with beds containing marine carboniferous fossils, thus giving further evidence, were any more needed, of the carboniferous age of the early Gondwána deposits.

For those on the look out from the Himalayan side Mr. Griesbach's notes of his traverse from Turkistán to India seem a little surprising, though perhaps his previous sections of the western prolongation of the Hindu Kush should have suggested the event. He crossed the Hindu Kush by the Chahárdar pass, north-west of

Ghorband, where the range is represented as in full force, but on the whole section up to Peshawar he found no rock that he took to be older than carboniferous. There were in the axis of the ranges immense intrusions of the syenitic granite, already noticed far to the south and west, and with it a considerable exhibition of metamorphosed rocks, but these were all taken to be carboniferous or newer. It is noteworthy, as consistent with the rest, that the axes of disturbance maintained the predominant east-west direction throughout, even where the Hindu Kush of the maps trends north-eastwards.

The Himalayan point of view mentioned above will be best illustrated by a notice of the contemporaneous observations made by Dr. G. M. Giles in the country beyond Gilgit. On the Himalayan side, it will be seen from Mr. Lydekker's map of the Kashmir territories (Memoirs, Vol. XXII), that the whole of the north-western quarter (Gilgit, Astor, and Baltistan) is a geological waste, a few patches of jura-trias, carboniferous, and silurian formations isolated upon a great expanse of crystalline metamorphic rocks which, though probably including some converted palæozoics, were taken to be largely made up of older (? archæan) gneiss, the continuation of that forming the Ladak axis. Dr. Giles does not pretend to be a geologist, but he made some excellent observations of the physical features of the ground traversed, which included a very large area, from the Pamir through Wakhan and eastern Badakshan (across the Hindu Kush, at its supposed roots), and back through Chitral and Yassin. From the very poor specimens brought back by Dr. Giles it would be inferred that the whole of that large area presented only an extension of the conditions known in Baltistan : no trace of a fossiliferous rock was seen, crystalline and schistose rocks greatly preponderated, with only a few less altered slaty specimens. Dr. Giles further observed that throughout the greater part of the area, the eastern and central, an east-west strike was very constant ; while on the west side, *i.e.*, on what is represented as the strike of the Hindu Kush, the prevailing strike of the rocks was north-south, though often irregular. Geologists will understand how indefinite must be the inferences from such data, but there seems at least a distinct contrast brought out, where some at least looked for a tie. There remains about 100 miles of unknown ground (Kafiristan) between the nearest parts (Charikar and Chitral) of the areas under notice, but the notion of structural (axial) continuity seems altered as if the relation of the Perso-Afghan system to the great (?) archæan massif of the Pamir was quite different from that of the Himalayan system to the same, the latter being direct (axial) and the former only secondary (fringing) ; so that the only structural continuity between the two systems is to be found in the narrow stratigraphical isthmus (or strait), in the centre of which stands Attock on the Indus.

Geology will certainly be the chief loser by the indefinite postponement of the proposed Mission to Lhassa. It had been settled that Mr. Oldham was to have gone as geologist, and I have no doubt he would have made the best use of his opportunities.

The Lhassa Mission.

Publications.—There was no issue of the Memoirs during the present year. These are only occasional publications ; when some special area, involving several seasons' field work, happens to be completed, or some other work of greater length than can conveniently find place in the quarterly Records. A Memoir on the Chhindwara coal-fields is now in the press, and Mr Griesbach's Himalayan Memoir is well in hand.

In the Records for 1886, being Vol. XIX of the series, there are 24 papers, with numerous maps and plates. Some of the papers were of considerable interest to geologists beyond the range of India.

In the Palæontologia Indica it has happened that several works have come to a natural close, or check, with the end of the year, and it may be expected that under present financial tightness this branch of our publications may not be so active as for the last few years. Mr. Lydekker has now pretty well cleared off all our fossil Vertebrata, but of course further collections will be made in due course from the same formations. The following parts of series X, the Tertiary and Post-Tertiary Vertebrata, were issued in 1886: Vol. III, part 7, Siwalik Crocodilia, Lacertilia and Ophidia; part 8, Tertiary Fishes; Vol. IV, part 1, Siwalik Mammalia (Supplement); and part 2, the Fauna of the Karnul caves. A catalogue of the Siwalik Vertebrata in the Museum, by Mr. Lydekker, was also published (in two parts). The Survey may be proud of having introduced Mr. Lydekker to a line of work in which he has already earned much reputation.

With the fasciculus on the Echinoidea of the Makrán series of the coast of Biluchistán and of the Persian Gulf, published in 1886, Professor P. Martin Duncan, F.R.S., has completed a very portly volume, forming Vol. I of Series XIV—the Tertiary and Upper Cretaceous fauna of Western India. Dr. Duncan's work comprises the Corals and the Echinoidea of the Sind collections, all the rest of which remain to be worked out.

Dr. Waagen too has well nigh finished his great volume on the fossils of the Productus limestone of the Salt-range. Part 6, the Cœlenterata, was issued in 1886, and a good part of the text and plates of the remaining small fasciculus on the Hydrozoa is in hand for publication. The whole will form a text of about 1,000 pages with a large volume of plates. This will be about half of the projected work on the Salt-range collections now in Dr. Waagen's hands. The remaining volumes will each be scarcely half the size of the first one: Vol. II, on the fossils of the Ceratite beds, and Vol. III, on the fossils of the Newer Mesozoic formations, as indicated in the introduction (p. 3.) to Vol. I. The fourth volume, in three parts, will give the full discussions of the palæontological and geological characters of the respective formations. Dr. Waagen's last renewal of engagement terminated with the year under notice; but it is earnestly to be expected that Government will sanction an arrangement that will permit of his completing this very important work.

A last part of Vol. IV, Series XII, was also issued at the end of 1886, on the fossil flora of some coal-fields in Western Bengal; and in the introduction to the volume Dr. Feistmantel gives a review of the recent discussions on the correlation of the Gondwána system. For the flora itself, Dr. Feistmantel's judgment is authoritative; but he has gone hopelessly astray in dealing with the geological elements of the question.

The two first parts of the Manual of the Geology of India, issued in 1879, have been out of print for some time, and the question of rewriting it has been much upon my mind. Parts of it would require abridgment, leaving local information to be sought for in the special Memoirs; and parts of it would need alteration and addition in view of extended information. The greater part of the two volumes was written by Mr. Blanford, who was for the time relieved of other work. To rewrite

the whole while carrying on the manifold current duties of the Survey has been more than I could attempt in India with any justice to either.

Museum.—The Geological Museum is in excellent order. Some valuable specimens of minerals were presented, Canadian specimens by Sir William Dawson, and English specimens by the British Museum. A good specimen of a meteorite that fell in South Arcot was sent in by the Collector of the district; a large portion of it was forwarded to the British Museum, also a [good specimen] to the Madras Museum. Mr. Mallet reports very favourably of the work done by Mr. Blyth as museum and laboratory Assistant.

Library.—The library is in good order. There were 2,199 volumes or parts of volumes added during the year; 1,470 by presentation or exchange, and 729 by purchase. I would here gratefully acknowledge the to me invaluable service rendered this year, as always, by Mr. W. R. Bion, as Librarian and Registrar, in charge of the office. Without an efficient and thoroughly trustworthy officer in this post, there would be endless inturruption and anxiety for the Head of the Department.

The employment of Natives as geologists.—For the last 15 years this has been a burning question for the Geological Survey of India, and as for almost the whole period the opposition to the proposal has fallen upon me, whether as officiating or permanent Head of the Department, I wish to explain overtly, especially to the natives themselves, the reasons that have guided me, though I can only do so very briefly. I would first indicate the speciality of the case in the general question of Government employment as due to natives—a principle which I entirely accept, if limited by reason: this small Department is a mere drop in the ocean of employments under Government, and the field-duties involve no intercourse with the inhabitants—the geologist goes about with map hammer and compass and need interfere with no one. These are collateral (administrative) reasons against any urgency for such appointments, if the special reasons against them are strong. The difficulty on this latter side is to get people even to understand the reasons, whether technical or intrinsic; and men in power are very loth to admit that there is anything they cannot grasp.

The special reasons then are, that the Survey has no duties of a mechanical nature, to which and through which it would be possible to break-in the uninitiated; that the facts it has to deal with are not facts in the usual meaning, as immediately appreciable by the senses,—mankind was for long familiar with stones before the geologist arose to put meaning into them; the facts he deals with are imputed to the stones by the interpretation of their characters as visible and tangible, through the knowledge of the various agencies of nature as studied in the physical sciences. The geologist's work is therefore sound and useful or false and misleading in proportion to his real acquaintance with the actuals and the principles of the exact sciences, and unless he reaches a certain standard of excellence his work is absolutely useless, or worse. In this respect the geologist is unique. A doctor may acquire a useful skill in the practice of medicine without being anything of a biologist; an engineer may do fair work with little or no knowledge of mechanics; a man may be a surveyor (of the earth or sky) without any proper knowledge of geodesy or astronomy; because in all these businesses there are practical rules by which ordinary work can be safely executed, and there would be no sufficient reason for excluding natives

on the ground of their ineptitude for original scientific work. Geology is the opposite of all this: there is no operation called for; every act in its service is an independent judgment upon very complex inductive facts through an accurate knowledge of physical phenomena and their laws; if not scientific it is nonsense. Further it is to be noted that the data upon which the geologist has to frame his judgments are for the most part very scanty: from occasional scattered sections or single outcrops he has to attempt the representation of the rocks as they lie underground and of their remote history. Thus, though based on the exact, it is itself the most inexact of sciences, and eminently demands conscientious and sober judgment. There is no science with which it is so easy to acquire a superficial acquaintance and to play the impostor. It is therefore evident that though eminently suited as an element of primary education, to open the mind of the young to the interpretation of nature, geology is eminently unfit as an introduction to scientific work, even for those in whom the aptitude may be presumed, much more unfit for natives with whom no such presumption is apparent, and in whom the disqualifying proclivities are very pronounced, especially in Bengalis.

I might leave the matter in this sufficiently presumptive state, but my chief object would be missed—to bring the native (and especially the Bengali, as the one most in error) to reflect upon himself a little. The impostor, in the most objectionable sense of the word, only deceives others; whereas the Bengali deceives himself. He seems fully convinced that with but a little more teaching he could take the lead in everything. In the question under notice, that of science, this opinion betrays a quite stupendous failure of the missing inductive faculty. What are the facts? A large number of the chiefs in the annals of science in Europe did not have a tithe (if any at all) of such scientific teaching as has been thrown away upon the Bengali youth for the last 50 years; they were self-taught men. In most considerable towns of England there are societies of workers in science. From how many a village of England and Scotland have we not heard of poor men —cobblers, journeymen tailors, masons, &c.—who have half starved themselves in the pursuit of some scientific object? In all, the mental germ was there, and it grew in spite of every want and obstruction. In Bengal the word of knowledge has been preached for the last two generations, but *in no single case* has it found the needful germ in which it might come to maturity and bear fruit in original scientific work; it seems only to develop a more obnoxious kind of weed, words of science without substance. In the medical and engineering services they have for long had like teaching and opportunities to those from which Darwin, Huxley, Tyndall and a host of others have arisen, but of like result in Bengal there is no symptom even. For a still longer period the practical results of the new knowledge in the shape of material progress have been displayed with ever increasing energy from the West, but neither has this awakened in the oriental mind a power to do likewise. Of imitation there is no lack, but of creative power there is no sign. If this is not a demonstration on the part of the Bengali of his ineptitude for science—that the presumption aforesaid is a hard fact—evidence counts for nothing. He would do well to take it to heart, if by any means he may correct his failing. Meanwhile, even if there were not particular evidence to confirm it, I hold this as sufficient warrant for objecting to the appointment of natives to the slender staff of the Geological Survey.

It would be wrong not to offer any elucidation that suggests itself of so prevalent and mischievous a delusion; for there are not a few very able men who more or less share the Bengali's persuasion of his own intelligence, and I am not at all concerned to dispute their position, because in fact, whatever their mental potentiality may be, their learning is in kind very much on a par with his, and in dialectical skill he may be quite their equal; so they are as incredulous as himself that he should not be able to master such a simple thing as geology. The question cannot, in truth, be argued as one of degrees of intelligence; it is essentially a specific difference. If there is anything new under the sun it is positive knowledge; and it is no less marked as a modern characteristic of the Western man. This is simply another way of stating the facts already set forth. Whether the difference is temporary or not is a question for the future. All manner of biological and psychological complexities might be involved in discussing the question; I will only give a superficial indication of the contrast suggested between learning and knowledge; it is an appropriation of the admirable distinction drawn by Dr. Newman in the Grammar of Assent between 'real' and 'notional' apprehension, as the characteristic difference between efficient and non-efficient faith, or rather between faith and profession. In the former there is such a vivid conception of the dogma as real, that the subject has no power but to obey; while in the latter, profession is merely intellectual in the most superficial sense. Dr. Newman's application of the distinction is actual enough, but obviously artificial and delusive; the conviction (faith) thus wrought by persistent imagination would be just as real and just as good evidence for dogma in the case of the Indian jogi as of the Christian martyr. In our present contention the terms are beautifully applicable: positive knowledge may be taken up by a real or a notional apprehension; the former is only attainable as a direct revelation of nature herself to the earnest student, in whom faith in nature is the needful germ; from this indeed there springs a conviction which need no longer be called faith, it is knowledge, the only 'real apprehension.' With it will expand the faith from which it sprung, until together they cleanse the earth and man. But of course the formulæ of science can be acquired and dealt with notionally, like any other barren knowledge or learning; and for this kind of accomplishment the Bengali has quite a special genius. Perhaps the needful germ of faith in nature has not yet descended to him; he only believes in the dictionary.

Personnel.—Mr. Mallet was absent on medical certificate from the 30th of April to the 25th of November, Mr. Jones officiating for him as Curator. Mr. Hughes was absent on furlough from the 20th of May to the 25th of November. Mr. Fedden returned from furlough on the 9th of November. Mr. Jones has been transferred to Upper Burma during the current season.

I am glad to be able to announce that Dr. Fritz Nœtling has been appointed by the Secretary of State as Palæontologist to the Survey, in succession to Dr. Feistmantel.

This being the last opportunity I shall enjoy of writing the annual Administration Report of the Department, I take the occasion to bid farewell to my colleagues, wishing that they may find as much pleasure as I have found in the performance of our work.

CALCUTTA,
The 31st January 1887.

H. B. MEDLICOTT,
Director of the Geological Survey of India.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1886.

BALLAARAT.—School of Mines.
BALTIMORE.—Johns Hopkins University.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Science.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
,, Natural History Society.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRESLAW.—Silesian Society.
BRISBANE.—Queensland Branch, Geographical Society of Australasia.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Geographical Society of Belgium.
,, Royal Malacological Society of Belgium.
,, Royal Natural History Museum of Belgium.
BUCHAREST.—Geological Bureau.
BUDAPEST.—Hungarian National Museum.
,, Royal Geological Institute, Hungary.
BUENOS AIRES.—National Academy of Sciences, Cordoba.
BUFFALO.—Society of Natural Sciences.
CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Editor, Indian Engineer.
,, Indian Museum.
,, Meteorological Department, Government of India.
,, Survey of India.
,, The Calcutta University.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE MASS.—Museum of Comparative Zoology.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey.
DELFT.—Polytechnic School.
DIJON.—Academy of Science and Arts.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
,, Royal Dublin Society.

DUBLIN.—Royal Irish Academy.
,, Science and Art Museum.
EDINBURGH.—Royal Scottish Society of Arts.
,, Scottish Geographical Society.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Glasgow University.
,, Philosophical Society.
HAMILTON, CANADA.—The Hamilton Association.
HARRISBURG.—Second Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Okonomische Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Sciences.
LIÉGE.—Geological Society of Belgium.
LISBON.—Geological Survey of Portugal.
LONDON.—British Museum.
,, Geological Society.
,, Iron and Steel Institute.
,, Linnean Society.
,, Royal Asiatic Society of Great Britain and Ireland.
,, Royal Geographical Society.
,, Royal Institute of Great Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
MADRID.—Geographical Society.
,, Royal Academy of Sciences.
MANCHESTER.—Geological Society.
,, Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
,, Geological Society of Australasia.
MILAN.—Royal Institute of Science, Lombardy.
,, Society of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
,, Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
NAPLES.—Academy of Science.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—The Editors of the "American Journal of Science."
PARIS.—Geograpical Society.
,, Geological Society of France.
,, Mining Department.
PENZANCE.—Royal Geological Society of Cornwall
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.

PISA.—Society of Natural Sciences, Tuscany.
ROME.—Royal Geological Commission of Italy.
„ Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
„ Imperial Academy of Sciences.
SALEM MASS.—American Association for the Advancement of Science.
„ Essex Institute.
„ Peabody Academy.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
STRASBURG.—Royal University.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Linnean Society of New South Wales.
„ Technological, Industrial and Sanitary Museum.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
„ Imperial Natural History Museum.
WASHINGTON.—National Academy of Sciences.
„ Philosophical Society.
„ Smithsonian Institution.
„ United States Geological Survey.
WELLINGTON.—Geological Survey of New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.
„ Seismological Society.
YORK.—Yorkshire Philosophical Society.

The Secretary of State for India.
The Governments of Bengal, Bombay, Madras, North-Western Provinces and Oudh, and the Punjab.
Chief Commissioners of Assam and Burma.
The Commissioner of Northern India Salt Revenue.
The Resident at Hyderabad.
Foreign, Home, and Revenue and Agriculture Departments.

Field-notes *from* Afghánistán: (*No. 4*)—*from* Túrkistán *to* India, *by* C. L. GRIESBACH.

Introduction.—The return march of the Afghán Boundary Commission to India, over the Hindu Kúsh and through Kabul, completed my geological reconnaissance of Afghánistán, and it has in a certain degree connected my work with that of my colleagues on the north-western frontier of India.

As I have had nearly always to conform closely to the movements and march of the Commission, opportunities for geological observations were naturally extremely limited, but my chief regret in connection therewith is, that I could not devote more time to the country lying north of the Hindu Kúsh.

I received permission to march to Charikár in advance of the Mission head-quarters, which moved two days behind me. I therefore left the Tangi Shadián (south-east of Balkh) on the 18th September 1886, and marched through Tashkhurghan and Haibak to Ghori, which is one of the districts of Badakhshán. Thence I went over the Chahárdar pass to Siáh Gird, from where I made an excursion to Farinjal. From Búrj-i-Gúl-Ján I was recalled to meet H. B. M.'s Commissioner at Siáh Gird. The remainder of the march to India brought us through Charikár and Kabul by the Khaibar route to Peshawar, where we arrived on the 1st November, having altogether been absent from India two years and two months.

Physical Geography.—Regarding the geographical features of the country north of the Hindu Kúsh which I traversed on this return march, there is little to say in addition to the description given in my last paper of the area between Bamián and Tashkhurghan.

Between Haibak and the Chahárdar pass I crossed the south-west corner of Badakhshán, the general physical characters of which may be said to be a continuation of the country between Haibak and the main watershed. It is drained by the headwaters and affluents of the Kundúz and Aksarai rivers; the latter in its upper course being known as the Súrkh Rúd. I had to cross its main branch near Dahána Iskár, where I found it a considerable volume of water, flowing in a deep valley of erosion. Numerous smaller streams drain from the main range of the Hindu Kúsh into the Súrkh Rúd, and most of these deep branch-valleys form routes to and over the Hindu Kúsh into the valley of the Ghorband river, which with its many branches forms one of the headwaters of the Kabul river.

Orographical and geotectonic features.—The outline description which I have given of the ranges between Bamián and the Túrkistán plain in my former report, equally applies to the entire section between India and the Oxus, as far as regards the general character and origin of the hill ranges. That is to say, it is a more or less continous succession of anticlinals between Attock on the Indus and the plains of Túrkistán, arranged in lines running more or less from west to east. These are accompanied by outbursts of igneous rocks along far stretching fissures of probably post-cretaceous age amongst which syenitic granite and traps are most conspicuous.

The lines of fissure correspond generally with the direction of the anticlinals, although at several points the reverse is clearly seen. Whether the latter case holds

good in the ranges which form the system of the north-east Hindu Kúsh and the ranges of Kafiristán I cannot say, but think it is probable.

Intrusions along lines of fissures, some of them on a very large scale, are seen in the Hindu Kúsh range, the Paghmán hills, the hills around Kabul and east of that city where they form the eastern Lataband and many of the minor ranges on the route to India.

Anticlinals of the Kara Koh and Karmard.—The high anticlinals of the Kara Koh and the Karmard neighbourhood flatten out considerably as they strike eastwards, forming wide depressed table lands between the lines of folds. Such for instance are the flats south-east of Haibak and Ghori, which are divided by widely arched anticlinals. South of Ghori the cretaceous rocks, which form the main mass of the country, rise again into a series of wide arches, which are eventually lost or at least very much obscured by the eruptive rocks of the Hindu Kúsh. The Zindjitak Kotal for instance leads over one of these wide anticlinals, the southern flank of which is denuded by the system of the Súrkh Rúd. The Hindu Kúsh is formed probably by a system of parallel flexures, which result in a series of separate ranges as it were, but the structure is greatly obscured by intrusive igneous rocks, chiefly hornblendic granite, which has altered the neighbouring formations into metamorphic-schists. The main mass of the Hindu Kúsh is a mighty chain with elevations of from 14 to 16,000 feet even in its south-western portion, and it bears distinct traces of having undergone extensive glaciation in recent geological times.

The eastern half of my last section in Afghánistán belongs to the drainage of the Indus, by the basin of the Kabul river, which with its many affluents has deeply eroded the southern slopes of the Hindu Kúsh and the ranges south and east of it.

The country still bears the same character of great anticlinal folds forming parallel ranges, with intrusions of granite and trap which have metamorphosed the greater part of the sedimentary strata composing these ranges. Here the general strike of the intrusions is across the direction of the anticlinals, being mostly in a line from south-west to north-east, whereas the direction of the anticlinals is nearly uniformly from west to east.

Literature.—The literature relating to matters connected with the geology or mineral resources of Afghánistán is very limited, and is mostly confined to descriptions of places and districts on the frontier or of Southern Afghánistán.

The only authors which I found treating of geological matters connected with Northern Afghánistán are the following:—

P. B. LORD—Some account of a visit to the plain of Koh-i-Dámán, the mining district of Ghorband, and the pass of Hindu Kúsh, &c., Jour. As. Soc. Beng., Vol. VII, page 521.

J. PRINSEP—Report on ten specimens of coal from Capt. Burnes. Jour. As. Soc. Beng., VII, page 848.

MAJOR VICARY—On the geology of the Upper Punjab and Peshawar. Quart. Jour. Geol. Soc., VII, 1851, page 38.

DR. A. FLEMING—On the Geology of part of the Sulimán range. Quart. Jour. Geol. Soc., IX, page 346.

CAPT. HAY—Fossil shells discovered in the neighbourhood of Bajgáh, Afghánistán. Jour. As. Soc. Beng., IX, page 1126.

E. E. DRUMMOND—On the mines and mineral resources of Northern Afghánistán. Jour. As. Soc. Beng., X, page 74.

H. B. MEDLICOTT—On geological specimens from Afghánistán. Proc. As. Soc. Beng., 1880, page 3.

H. B. MEDLICOTT—On rock-salt from the Kuram valley. Proc. As. Soc. Beng., 1880, page 123.

Geology.—The geological structure of the section between Túrkistán and Peshawar is simple, in spite of the great changes which have taken place near the numerous intrusions of igneous rocks.

The prevailing rocks belong still to the upper cretaceous period, mostly in the form of hard limestones covering with a thick skin the greater part of the area traversed. Below this, where deep erosion combined with high flexure has exposed the base of the cretaceous series, some members of the older formations appear. The "red grits" and dark shales of the upper jurassics are easily recognized, and are seen at several places; but only at one spot, on the Fazák or Bazák pass north of the Chahárdar pass in the Hindu Kúsh, did I see any rock, which could be identified as older than jurassic. The rock in question is, I believe, carboniferous, and is an eastern continuation of the Palú Kotal (near Bamián) carboniferous limestone.

The greater part of the country between the Hindu Kúsh and Attock shows little more than metamorphic and igneous rocks, in which only here and there shoals, as it were, of the upper beds of the mesozoic series were left intact, and those often are highly metamorphosed.

Part of the return march to India, namely the distance from Shadián to Haibak, was over ground I had already visited and described.[1]

Description of section between Shadián and India.—Starting from Shadián, south-east of Balkh, I descended into the Bactryan plain, part of the great valley of the Oxus, now filled with tertiary and recent strata and which is in process of dividing into two separate and parallel valleys.

I have had no better opportunity this time of examining in detail the tertiary beds of Tashkhurghan. In lithological character the Tashkhurghan series is not distinguishable from the Mathar or Bamián rocks. On a base of lower tertiaries and miocene marine clays[2] rests an enormous thickness of freshwater beds, chiefly buff and reddish coloured hard clays and sandstone, plant shales and grits, belonging to one structural whole and which I include in the pliocene series.

They rest with their older tertiary base conformably on the upper cretaceous (Exogyra) limestone, and are with the latter contorted and raised up, here and there even vertically. Near Tashkhurghan the hard Exogyra limestone beds pass at an angle of about 75° to 80° under the tertiaries, the whole series being favourably exposed by the Tashkhurghan river which forms a transverse valley (one of the finest gorges in Túrkistán) through the entire series.

The road to Haibak leads along the valley of this river, which cuts transversely through the whole system of flexures. Apparently there is a wide open synclinal north of Haibak which is bounded on the north by several narrow anticlinals and sharp folds. Inside the synclinal north of Haibak some members of the tertiary

[1] Rec., Vol. XIX, page 235.

[2] Mr. Ney Elias brought specimens of Ostrea multicostata, Desh. var., from the beds of Tashkhurghan. It is a miocene species, identical with similar forms found in the Herat province and at Kilif.

system are inclosed and can easily be distinguished by their bright colouring from the underlying dark grey cretaceous limestone. They form some of the lower slopes of the left (west) side of the valley, north-west of the town of Haibak. I did not examine them closely as they were too far off the line of march.

Near Haibak, where the river flows through this synclinal, it forms a wide and very fertile valley, but further north it cuts through several high anticlinals, producing a transverse valley with precipitous sides, often only a narrow gorge, as for instance near the village of Sáyád and south of Tashkhurghan.

The geological structure is exceedingly well exposed in this gorge, particularly near Sáyád, where the beds of the Exogyra limestone are highly contorted. The lowest portion of the anticlinal is seen to be coarse red grits and brick coloured sandstones of the "red grit group" (upper jurassic or neocomian). The centre of the flexure is just south of the Tashkhurghan gorge and there the red beds dip at a steep angle below the Exogyra limestone, but I question whether I could have made out the true relation of these red grits by simply marching along the route in this gorge. At least from the base of the narrow gorge the true relations of the red grits to the cretaceous limestone are not quite clearly seen. But during our residence at Shadián last summer I observed the same anticlinal at two other points. The Shadián streams erode the cretaceous limestone down to the red grits, which are *in situ* about a mile south of the Tangi Shadián, and they underlie the cretaceous limestone conformably.

To the east of the Shadián valley and parallel with it is the basin of Már-Múl, a picturesque highland valley, surrounded by enormous and precipitous cliffs. Here also the anticlinal is clearly exposed and the red grits are seen to be well developed, forming a thick band of densely red-coloured beds near the centre of the anticlinal; they dip below the outer (northern) flank of the arch, and also disappear below the high cretaceous cliffs which form the southern margin of the Már-Múl valley. The road which leads from Már-Múl over a high kotal into the Tashkhurghan river valley (east of Már-Múl) creeps along the up turned edges of the "red grits."

The Balkh-ab also traverses the same anticlinal, and the structure of it is laid bare on the steep hillsides forming the valley through which the Balkh-ab escapes to the Túrkistán plain. I have not been on the spot itself, but a clear view of the section may be seen from the high points south and south-east of the Shadián valley. The "red grits" are also here laid bare below the overlying Exogyra limestone.

The thick group of limestone beds which rest seemingly conformably on the "red grits" at Shadián and the ground east of it, shows much the same character which distinguishes this formation in other parts of Túrkistán. It forms high precipitous cliffs, generally of a very uniform white to grey, thickly bedded limestone, which besides corals also contains Exogyra, Ostrea, Hippurites sp., Inoceramus, Terebratula, etc.

In some places the limestone is porous, soft and chalky with strings and nests of flints. The upper beds of it are a white porous limestone and shell breccia with many fossils, chiefly bivalves, amongst which a large species of Ostrea is conspicuous. I observed this upper horizon especially well developed at Kafir Kala, about 11 miles south of Shadián, and on the high ground between these points, where

it forms the gently undulating grassy downs which cap the Shadián anticlinal, and then gradually slope down to the synclinal depression south of it.

Lithologically this horizon is identical with the uppermost beds of the cretaceous series of North-West Afghánistán; the cliffs of Houz-i-Khudá, between Chakáu and Kálanáu north of Herat consist of precisely the same rock, and seem also to contain similar fossils. It is quite possible that this portion of the Exogyra limestone series will have to be included in the lower eocene. The latter seems closely connected with the upper cretaceous group in Western Persia and the Armenian frontier and a distinct division between the two formations is nowhere visible.

On the route from Tashkhurghan to Haibak the character of the cretaceous group remains the same throughout, and I believe that the entire thickness (about 2,500 feet) of limestones aud marls which composes this formation represents the upper cretaceous horizon. I could not discover any unconformity between the latter and the upper jurassic red grits which are seen to underlie the former near Sáyád, south of Tashkhurghan, at Már-Múl and places west of it. That this is not the case in all sections is well shown in the cliffs immediately south of Haibak, near the village of Doáb, where the unconformity between the red grits and the Exogyra limestone is very marked. (See Records, Vol. XIX, page 249.)

Haibak itself lies in a wide synclinal in which some few remains of tertiary beds are traceable. They form the low slopes and terraces on the left side of the valley, and are evidently conformable to the underlying cretaceous formation.

The road from Haibak to Dahána Ghori crosses two low kotals, east of the Kotal-i-Archa and a spur which separates the Chasma Shir basin from that of Dahána Ghori.

Both these kotals cross ranges which are the continuation of the anticlinals of Rui and Doáb, south of Haibak. Between each of them extend wide synclinal troughs, which even become depressed tablelands with nearly horizontal bedding. The latter is well seen between Haibak and the Kotal on the road to Robát. I believe some of the lower cretaceous marls crop up below the Exogyra limestone; the lithological character is precisely identical with the white Baculite marls of Zulfikár and Zorabád. None of the jurassic or older formations crop up along this route.

Near Robát, on the road to Dahána Ghori, and between the latter place and the Kotal-i-Zinjiták trap dykes, with bosses and strips of syenitic granite traverse the cretaceous limestone. Towards the Kotal-i-Zinjiták the number of these intrusions increases rapidly and they widen in extent. The direction of the dykes runs more or less parallel with the strike of the anticlinals, and south of the Zinjiták Kotal the only prevailing rocks are of igneous nature. One enters there a broad belt of intrusive rocks with some inclusions of semi-metamorphic strata, forming the main range of the Hindu Kúsh between the Súrkh-Rúd and the Ghorband valley.

The same formation of more or less altered strata with intrusions of granite and traps is seen from the south-western corner of Badakhshán to Attock on the Indus. I believe it is possible, however, to distinguish the main divisions of groups in spite of the alteration which has taken place near the contact with the igneous rocks.

How clearly defined the boundary of the igneous belt with the cretaceous limestone is, may be seen from the heights above the Dahána Iskár or from the Kotal-i-

Fazák (elevation above sea-level 10,000 feet), south of the former. Looking back on to the country lying northwards, the dark traps and granitic rocks contrast strongly with the light coloured limestones of the cretaceous formation. The igneous intrusions form quite a network of dark lines near the boundary of the cretaceous limestone, and this can be seen to extend far away east and westwards of the Zinjiták Kotal. The boundary runs almost due west and east.

From that point to the Indian frontier there is very little change in the geological structure. The most prominent amongst the igneous rocks of the Hindu Kúsh belt is a syenitic granite, apparently of the same lithological character, and belonging to the same mass of intrusion as the granite of the Northern Ak Robát Kotal, south of Saighán. I found the syenitic granite in great force as a wide belt between Chahárdar camping ground and the top of the Chahárdar pass 14,100 feet, which leads over the Hindu Kúsh. The trend of this belt of granite is almost due west to east and seems to compose the greater part of the Hindu Kúsh range. Besides this the entire region between the Súrkh Rúd and the top of the Chahárdar pass is traversed by numerous granite veins and dykes. The entire series of sedimentary beds which occupy the ground between the granite intrusions has been completely altered by the latter, and has been converted into a succession of metamorphic strata. The prevailing rock is a gneiss with mica schists, but dark-coloured phyllites with enclosed indurated limestone are also common. Near Sar-i-Iskár great trap masses have intruded in the syenitic granite and are found as dykes throughout the mass of hills, over which the Kotal-i-Fazák leads. The top of the latter shows a few fragments or shoals of hard grey limestone, locally converted into a sugar-grained white marble, which I believe (on purely lithological grounds only) to be cretaceous. In that case I may perhaps look upon the metamorphic beds immediately underlying the white marble as representing the "red grits" and the plant-bearing series. Below this section of the metamorphic series, on the south slope of the Kotal-i-Fazák, I noticed some beds of very hard splintery, dark limestone, which underlies the metamorphic, subcretaceous series comformably. In it some sections of shells (brachiopods) are visible, and sections of encrinites are not uncommom. It would be difficult to assign any definite age to this limestone, but the lithological character of it is very similar to that of the carboniferous limestone of the Palú Kotal near Bamián, whilst its geographical position in the strike of the latter would point to the possibility of the palæozoic series also being represented in the Hindu Kúsh.

Between this point and the Koh-i-Dáman near Chárikár the Hindu Kúsh is seen to be formed by a succession of anticlinal folds, traversed by igneous rocks, amongst which syenitic granite is again very conspicuous. As the whole complex of sedimentary strata is entirely changed by contact with these intrusive rocks, any correlation with the sedimentary groups of Túrkistán must be very uncertain.

As I have shown, the section of the Fazák pass may represent the whole series from the carboniferous to the cretaceous formation. The lowest and highest beds of the series at least have some lithological characters in common with these two formations.

Immediately south of the Fazák Kotal, near the camping ground of Chahárdar great masses of intrusive hornblende granite appear and south of it nothing else is seen but various varieties of the same rock until the top of the Chahárdar pass

(14,100 feet) is reached where a few shoals of limestone are enclosed in the granite and have been converted into a fine-grained white marble. South of the pass, on the slopes of the Hindu Kúsh which lead down to the Ghorband valley, large masses, some showing traces of the original structure, of light grey limestone rest seemingly conformably on a series of semi-metamorphic rocks, closely resembling in litho, logical character the series of the Fazák pass. In the gorge of the Ghorband river between Búrj-i-Gúl Ján and Charikár I also noticed several thin seams of impure graphite in beds of micaceous schist, which resemble the altered beds and graphite seams of the section between Ak Robát and Saighán.

If my supposition is correct that these beds are identical with the Fazák Kotal series and also with the Palú and Ak Robát Kotal section, then it would appear that the carboniferous and supra-carboniferous beds of Saighán strike across the Hindu Kúsh, and form a wide belt of greatly crumpled strata, which have been traversed and intruded by igneous rocks, amongst which the most conspicuous is a hornblendic granite. The belt of the latter, which is only of narrow width north of the Ak Robát Kotal near Saighán, widens out so tremendously that the entire main range of the Hindu Kúsh where I crossed it seems formed of it. It appears therefore that the belt thins out westwards; and in all probability it will be found that in the valley of the Upper Balkh-áb (Rúd-i-Band-i-Amir) a carboniferous section will be found, free from disturbing granite intrusions.

On both sides of the Hindu Kúsh there are also cretaceous rocks (limestones) resting on the older and altered strata; here I could not detect an uncomformity, which is very plainly seen in the Bamián Haibak sections.

The remaining distance from Charikár to Peshawar was done by long marches and along a made road, which offered few good opportunities of making geological observations. The valley and basin of Kabul itself is chiefly composed of igneous rocks (hornblendic granite and traps) with some few portions of altered strata, which crop up at a few places near the margin of the valley, and which form the ranges of the Takt-i-Sháh, the Sher Darwaza, the range west and north of the Kabul lake, &c. The valley is filled up by recent and sub-recent formations which form the rich soil for which Kabul has been famous since the earliest times.

Far to the east and north-east, light grey precipitous cliffs are seen to overlie the dark igneous and altered series of Kabul, and I believe I may not be far wrong in identifying these light coloured cliffs with the upper cretaceous, which plays such an important role in the structure of Afghánistán.

The hills of Bútkhák, through which the Kabul river has formed a narrow gorge, the Tangi Ghároo, consist of the well-known red grit group with overlying cretaceous limestone of typical character. The section dips east, but I found that the Lataband and the hills eastwards are formed by a succession of anticlinal flexures, some of them exceedingly perfect. The road from Bútkhák over the Lataband pass to Seh-i-Bába leads over a succession of low spurs of altered cretaceous limestone and igneous rocks associated with the latter. The rock *in situ* on each side of the valley at Seh-i-Bába I found to be a dark trap with veins and masses of light green serpentine.

Some of the lower spurs on that route are hidden under thick deposits of sub-recent gravels and reddish clays, which form high level terraces in the Kabul river basin. The road from Seh-i-Bába to the head of the Pari Darra, past Jagdallak

fort and over the Jagdallak pass, leads over the same series of altered strata. Near Jagdallak it is a gneissose schist, highly contorted. Further on the road skirts this formation, passing over a succession of low kotals and undulating ground (Pezwán Kotal, 44th hill, &c.) down to the Gandamak plain.

The greater part of the ground so traversed is composed of sub-recent and possibly pliocene formations. The uppermost portion of them is composed of conglomerates and fine reddish grey sandy clay, very like the aerial (loess) formations of the Chúll. The lower beds, which nearly everywhere show a decided south-east dip, are chiefly composed of soft grey (pepper and salt) sandstones and flaggy sandstone-shales with conglomerates. These deposits bear a strong resemblance to the Manchhars and Upper Siwaliks and are quite distinct from the conglomerates and sands, which are discordantly reposing on them.

Between Gandamak and Rozabád the road crosses a series of low spurs all running more or less north or north-east; they are all composed of soft sandstones and conglomerates (Upper Siwaliks) with a rolling dip to the east and are overlaid by horizontally bedded loess and conglomerates of recent origin. The latter forms wide gravelly terraces or low plateaux, ending in steep scarps.

East of Rozabád, the higher ranges come close up to the river, and consist there of altered strata, highly contorted, grey gneissose schists, and intrusions of trap and serpentine, which form quite a network of dykes and veins in the crystalline schists. The same formations are seen to be *in situ* on the opposite side of the Súrkh-áb, in the Siáh-Koh range. The valley widens out to extensive and very fertile alluvial plains near Jalalabád and Chahárdeh. The road skirts the more or less solated ranges east of Ali Boghán and the hills of Basawal. They consist of altered strata and schists with trap intrusions, and are part of the Siáh-Koh structurally.

The same remarks apply to the spurs which are crossed between Basawal and Dakka on the south side (right bank) of the Kabul river.

Near Haft Cháh, the road enters the narrow valley which leads to the Lundi-Kotal. The prevailing rock is altered limestone (cretaceous?) and schist, amongst the latter a fine-grained grey gneiss with mica schist and greenish grey phyllites. No change of rock is perceptible, excepting that some of the grey limestone near the west entrance into the Khaibar pass seems less altered and closely resembles the upper cretaceous limestone of Afghánistán. Similar rock is seen near the eastern (Indian) entrance into the Khaibar. I have looked in vain for fossils in any of the rocks. The Khaibar limestone, however, is undoubtedly part of the same limestone formation which forms the Kohat pass and Afridi hills south of the Peshawar plain, which are cretaceous and are overlaid conformably by the nummulitic limestone of the Kohat District.

Notes made during the last war in Afghánistán.—As will be seen from these notes on the country between Kabul and Jamrúd, the section is not a very favourable one; fortunately we possess a few stray notes on the neighbouring areas, collected during the progress of the last war which afford a slight aid in interpreting the structure of this part of Afghánistán.

From specimens[1] which were brought during the last war from Northern Afghán-

[1] H. B. Medlicott, Proc. As. Soc. Beng., 1880, p. 3.

istán, it appears that the north side of the Sikaram in the Saféd Koh range is composed of transition rocks, amongst which magnesian and calcareous beds predominate.

From the western flank of the same hill and from an elevation of about 10,000 feet, Dr. Aitchison brought specimens of unaltered shales with fucoid markings. A similar rock is *in situ* on the south side of the peak. From the Shalinar stream, east side of the Paiwar Kotal, a pebble of Lithodendron limestone was brought. The latter is possibly of carboniferous age. It would appear then that beds of palæozoic age accompanied possibly by older mesozoic strata exist in the Saféd Koh range and form the highest part of it. Pebbles of palæozoic rocks, probably of carboniferous age, have been found by Major N. Vicary[1] near the Khaibar mouth near Jamrúd and both the locality last named and the Sikaram beds seem to belong to one belt of palæozoic strata, of which the Attock section is the eastern continuation.

The group of altered rocks between Jagdallak, Gandamak, and Ali Boghán may be outliers of the same formation.

Glacial. Recent formations.—In my former paper,[2] I had occasion to mention some of the deposits and traces of former glaciers in Afghán-Túrkistán. Since then I have seen by far the most perfect instances of recent glacial action, when crossing the Hindu Kúsh by the Chahárdar pass in October 1886. The road which leads from Chápdarra camping ground on the north side of the Hindu Kúsh to the top of the pass ascends a narrow straight valley, bounded on each side by steep cliffs, some of them crowned with perpetual snow. The bottom of the valley itself is greatly choked and partially filled with debris, which might be simply the detritus from the hillsides. Large cones and fans of fragmentary material descend from each small ravine on both sides. So far only the configuration of the valley, its nearly straight course and absence of larger side streams, would suggest the former presence of glaciers. But on reaching an elevation of 12,000 feet, one suddenly comes to a huge mass of debris, which closely resembles the recent accumulations near the lower end of a glacier. Large blocks, some of them of immense dimensions, are loosely mingled with angular fragments of every size and the whole is arranged like a dam across the valley. The hillsides (gneiss) are polished and grooved and the blackened surfaces glisten and shine in the distance like metal. All the larger blocks show extensive grooving and deep ice-scratches on their polished sides. This mass of debris lies at the base of a terrace filling the valley. The former glacier, of which this is the end moraine, was on the upper and raised portion of the valley. The latter bears the remarkable appearance of an ice-worn trough; it is wider than the valley below, and its base is now partially filled by finer debris, through which a small stream winds its way amidst a series of swampy pools. It is within the area of perpetual snow and the latter with frozen patches of ice lies on the hillsides and in sheltered depressions.

The valley looks as if the glacier had only quite recently left it. Moraines and glacial silt still lie as they were deposited. The head and catchment area of the valley close to the top of the pass (14,100 feet) is still rather thickly covered with frozen snow.

[1] On the Geology of the Upper Punjab and Peshawar, Quart. Journ. Geol. Soc., VII, p. 38.
[2] Rec., Vol. XIX, p. 263.

Glacial traces on the south slope of the Hindu Kúsh.—The descent from the Chahárdar pass to the Deh-i-Tang lies down a narrow valley of much the same character as the one just described. But the most interesting feature in connection with it is, that in this valley there are some small glaciers still remaining. Near the head of the valley, just south of the Chahárdar pass, at an elevation of 12,050 feet above sea-level, several small side ravines join; I noticed three of them were still filled with glaciers, and though they were very small, the moraine accumulations near their lower ends were enormous. Especially the one from the right side shoots off an enormous cone of large fragments, amongst which there are some very good examples of ice-scratched blocks.

Recent conglomerates.—Both in Túrkistán and the neighbouring South-western Badakhshán deposits of recent and sub-recent conglomerates, sands and clays are largely developed. The hills which skirt the cretaceous anticlinals between Haibak and Dahána Ghori are formed by these deposits which attain there a great thickness. Similarly the valley of the Súrkh-áb is partially filled by them.

The valleys belonging to the Kabul river drainage south of the Hindu Kúsh are to a large extent lined with terraces of conglomerates, as, for instance, the wide terraces of Siáh-Gird, Chahárdeh, etc.

These conglomerate terraces form quite a feature in the landscapes of the road east of Kabul, amongst which I may mention the terraces of Gandamak and Nimlah Bagh.

I believe these accumulations belong to the same age as the Indus gravel beds, which are seen to skirt the hills the whole way from Peshawar to Sind.

In the next number of the "Records" I intend giving a geological map of Afghánistán and part of Persia with a summary of the geological structure and mineral resources of Afghánistán.

CALCUTTA, *23rd December 1886.*

Physical Geology *of* West British Garhwal; *with Notes on a Route Traverse through* Jaunsar Bawar and Tiri-Garhwal, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

PART I.

Introduction.

In Part 2 of the Records for 1885 I described a fossiliferous zone of pre-tertiary age amongst the old mountain-building rocks which form part of the Lower Himalaya of British Garhwal. When that preliminary notice was published I had only been working for a short time in the district, and consequently the area treated of was confined, and no generalizations could be made. Since then, having spent another field season there, I am

able to make some additions to our knowledge of the stratigraphy of those parts. But, inasmuch as this part of the Himalaya is divided from ground which has been already geologically surveyed in Jaunsar Bawar by a broad strip of almost completely unknown country, *viz.*, part of Tiri-Garhwal, I am still compelled to put aside for the present all definite correlation between the rock systems displayed in Jaunsar and those upon which I have now been engaged. In consequence of this I shall still adhere to the method observed in my preceding paper of naming the series, when fossils are absent, after their prevailing lithological character; trusting to time, and a wider experience, to eventually make them one with the old established Himalayan formations.

British Garhwal has been topographically surveyed on the one-inch scale, and the principal object of my first season's work there was to settle down on some part of it where the strata showed signs of falling into a natural order, and then work from that point as closely as the advantages of a large-scale map would admit.

But, before doing so, I went through Jaunsar Bawar (the next British possession west-north-west of British Garhwal) for the purpose of making myself as thoroughly acquainted as possible with that already mapped district. From its no great distance from Garhwal it was thought that it might have many points of similarity, and so give one new to Himalayan work a useful basis to go upon.

From the northern extremity of Jaunsar Bawar I rapidly crossed by Tiri through native territory until I struck my own working district at Srinagar in British Garhwal.

Before coming to the main object of this paper I shall therefore briefly set down a few somewhat disjointed notes referring to my route traverse: not because they have any intrinsic value, but because of their possible bearings on past or future work.[1]

Jaunsar Bawar.

The southern parts of Jaunsar Bawar were examined by me in some detail with especial regard to the position of the Mandhali series in its numerous unconformable appearances near Chakrata. It is not my province to describe these rocks, with the questions arising from which Mr. Oldham is now engaged, but the numerous examples about which I have notes, from their containing clear blebs of quartz, fragments of felsites and a great deal of felspar and felspathic material scattered about in the matrix, gave me the idea of a rock produced by the degradation of felsites or granitic rocks and produced perhaps during a time of intermittent volcanic activity. North of Chakrata, the high Deoban ridge up to Mandhali, and some way beyond, was wrapped in deep snow, the product of a late storm, at the time of my visit; and work was therefore curtailed in a great measure. What I saw of the Mandhalis there left no doubt in my mind as to their identity with the rocks classed as the same a little south of Chakrata.

At Tiutar (near the Tonse) I made a careful examination of the Chakrata series to the east of the Konain-Mudhaul fault,[2] in order to solve, if possible, the question of inversion, and whether the igneous rock was intrusive or inter-bedded. From

[1] To make these route observations more intelligible it may be noted that Mr. Oldham's Bawars are taken by him to be about on the horizon of the base of the infra-Krol group of the Simla section, the Mandhalis being older still, but newer than the Deoban limestone (see Vol. XVIII, p. 4).

[2] See R. D. Oldham's "Note on the Geology of Jaunsar and the Lower Himalaya." Rec. Geol Surv. India, Vol. XVI, 1883, p. 193.

the presence of what appeared to be thin ash beds, associated with the igneous rock, I at first felt sure both must be inter-bedded, but until microscopic sections are cut there is a possibility that they may turn out to be merely crushed and pressure-foliated diorites. With regard to inversion, the lie of the beds as contrasted in deep gorges, and on the neighbouring mountain spurs south-west of Tiutar, inclined me in favour of the supposition of inversion; for to the eye there seems to be a steepening of the beds in towards the mountain; but, on the other hand, the limestone which lies apparently immediately below the igneous rock is a very whitey-grey, compact, and marble-like rock, such as could have been produced by the contact metamorphism of the igneous rock. In addition, south-west of Tesar Khert, where the limestone contains some magnetic iron in small crystals, the contact of the igneous rock has in places altered the latter, so that it now lies as amorphous lumps filling lacunæ among the joints of the limestone. From these facts the limestone must be older than the igneous rock, and, if the latter is inter-bedded, their present position must be the original one, and the inversion theory cannot be maintained.

From Tiutar I rounded the north end of Jaunsar Bawar and left British territory at the head of the Khunigadh river which divides Jaunsar from Tiri-Garhwal.

From the Khunigadh pass I descended, in a south-east direction, to Porohla.

Tiri-Garhwal.

Except for a mile or so from the pass, where there were some diorites and ash (?) beds, there was nothing met with but Bawar quartzites during the whole descent. They lie dipping slightly towards the north-east and never exceeding an angle of 20°. Their colour is white, and, when

Bawars.

seen through a lens, they appear to be made up of little angular fragments of clear quartz and apparently nothing else. They form the exceedingly precipitous ridge west of Gundalho, lying between the two branches of the Kamalada river, which meet at Porohla. The steep bare walls into which they weather utterly barred my progress at a point on the map above the *l* of Gundalho; but, with their low dip towards the north-east, they appeared to continue much higher up towards the main range running parallel to the Tonse. I have no doubt that these are identical with the Bawar quartzites of Mr. Oldham. Porohla lies in a widened and flattened valley, given over to cultivation, and called the Rama Serai, lying to the north-north-east from the village along the present line of the river.

Along its bed there must be an unseen junction between the Bawar quartzites just mentioned, and another rock which is petrologically a gneiss. Unfortunately

Gneissose rock.

both it and the Bawars themselves, in this region, have so weathered at the surface that in the few exposures that I could examine in a hasty march I found no reliable junction that gave me a clue as to the nature of the boundary. This excessive weathering into a fine gravel of the separated crystals of the gneiss and the disintegrated grains of the quartzite, is probably the cause of the flat cultivated stretch of the Rama Serai, the valley of which has become in this locality choked with the products of disintegration. I had the gneiss with me, gradually emerging from its weathered covering, up to, and beyond Kumalo; but, when the position indicated on the map by the *l* in Kumalo was reached, it came to an end, and Bawar quartzite and some schists

continued up to the ridge trending north from Saulda peak. The eastern boundary of this gneissose rock runs a little east of north to beyond Dokri, from the point just mentioned. This boundary is as difficult to unravel as the western boundary, for the uniform Bawars show but little dip, except where they rise in escarpments, or when schists come in among them, and even then the results are discordant.

With regard to the gneiss itself, its foliation planes, when visible, are roughly horizontal just as the Bawars are. It will thus be seen that stratigraphically no position can be assigned to it from the evidence before us, for it is not known whether the boundaries are natural or faulted; and, from the nearly horizontal dip found in every exposure, an average actual dip cannot be deduced. Then again, I have no evidence to bring forward as to whether the rock, provisionally named a gneiss, is by origin a gneiss or a granite. Petrologically it is identical with the rock of the Chor mountain, which has received much attention from Indian geologists. That rock, by Colonel McMahon's microscopical evidence, and by the still more convincing evidence of large and numerous included fragments of schist and quartzite found by Mr. Oldham and myself during the season's work of 1883-84, is by origin a granite; but whether the same can be said of this rock depends on how far an exact likeness between two rocks of this kind is to be deemed conclusive of their identity. At the same time, though willing myself to withhold judgment until more extensive mapping has been done, there is no doubt that the two rocks in so far as their mineral characters go *are* the same. There are the same quartz and felspar, with sometimes a predominance of the former; there are pale and black micas; and there are schorl crystals, developed here and there, and occurring abundantly in cracks and veins, just as they did in the gneissose granite of the Chor. In some places I found a decomposed greenstone, probably a dyke of diorite, in the gneissose rock.

From the east edge of the gneiss I crossed the ridge north of Saulda peak and followed a tributary of the Banale river, west of Kanal. The whole of the west side of this ridge was chiefly composed of the Bawar quartzites, showing no evidence of dip, except a general horizontality. At the summit of the pass, and on the east side, schistose beds came on, and continued until some inter-bedded diorites and dioritic ashes appeared below them. Then came more schists, and finally I struck in the stream bed a massive limestone of the Deoban type.

It will thus be seen that, on the east side of the gneiss, we have a set of outcrops inversely arranged to those of the west side. The following will illustrate this:—

WEST. Deoban Limestone.	Schists and igneous products.	Bawar quartzites.	GNEISS.	Bawar quartzites.	Schists and igneous products.	EAST. Deoban Limestone.

Now, the steep descent from the ridge into the tributary of the Banale, leaves the impression that the approximately horizontal beds to the east of the gneiss rank in order of superposition from the limestone below to the Bawar quartzite above; that is, we may assume an ascending series on that side of the gneiss from the limestone upwards. The west side of the gneiss is not so clear, but, from the undoubted identity of the quartzite with the Bawars there is the exact appearance there also of an ascending series towards the gneiss.

A seemingly absurd corollary follows from this: We appear bound to believe

in a gentle synclinal along the valley of the Kamalada, with the gneiss as the uppermost member of the series! Those readers who have followed the history of the geology of the Chor mountain will see that we have here exactly the same apparently unsolvable problem that at first proved too much for every one in the case of the Chor. It is true that we now have a partial answer in the case of that mountain, inasmuch as it is certain that its material has been in a condition of aqueo-igneous fusion sufficient to allow of its tearing off fragments of the neighbouring rocks among which it was intruded, and enclosing them in its substance, but we cannot assume the same explanation here until the same proofs in this case of included fragments, and the evidence of the microscope have been brought to bear on the question in this locality. Later on, I shall have to mention Kalogarhi mountain in British Garhwal, an isolated peak, also composed of this gneissose rock, and presenting in its neighbouring relations very much the same features. It also, at first, appears to lie in a synclinal, as a capping on the summit of the hill, and in many ways it may be looked upon as a miniature Chor. The explanation of the Kalogarhi rock rests, however, on the proved great age of the schistose strata amongst which it lies: although the schists there have the appearance of being the highest of the neighbouring formations. The proving of this involved much labour and time, neither of which could be given to the Rama Serai section on account of my rapid movements.

Deoban limestone.

Returning to the section down stream in the Banale river, we have the spur from the main ridge running towards Shishalu and dividing the upper branches of the Banale river, showing distinctly the various outcrops of the schists and the limestone as they appear to dip in towards the mountain and at a much higher angle than met with heretofore. The bed of limestone is not by any means thick, but between Shishalu and the ridge running east from Saulda peak, and between the last point and Palaita the thickness varies very much, becoming less as the outcrop is traced south by the last-named places to the Jumna. Beyond Palaita I could not see where it went to, but its line of strike from that place would carry it very well to join up with the Deoban limestone of Jaunsar near Lauri.

Shaly slates.

At Bigrar village (not marked on the map), which is half a mile above Deltu, the limestone beds have come to an end, and we come upon grey shaly slate dipping about 20° north-west. After a short thickness of these there comes beneath them a thin bed (not more than 60 feet) of a dark, micaceous, gneissose rock, finely foliated, and of very different aspect to that on the other side of the Saulda ridge. Of this, and other rocks collected during last season, I hope to make a thorough microscopical examination later on; I can now only say that the quartz is present in large quantities, showing the polysynthetic structure so common in gneiss of other parts of the Himalaya examined by Colonel McMahon.[1] No fluid or other cavities can be seen. The felspar is not so abundant as in a typical granite or gneiss, occurring in less quantity than the quartz; it is decomposed almost beyond recognition. Biotite is fairly represented, and there are a few needles of apatite. Whether the rock is an intrusion, or is metamorphosed *in situ*, is a question I cannot answer

Another gneissose rock.

[1] See Records, Vol. XVI, p. 144.

by any direct evidence. Its regular appearance bedded with the other rocks, and its lateral continuity between the stream and the ridge east of Saulda peak along the strike of the rocks, favours the idea of its being a true gneiss, and not a foliated granite; but, on the other hand, the selective metamorphism required to pick out a bed 60 feet thick and make it a gneiss without altering the surrounding rocks relatively at all, seems incredible.

Quartzites and slightly schistose slates.

Between Kanal and Goldar there come beneath this gneissose bed olive-grey quartzites, blue-grey quartzites, and finally slightly schistose slates, all dipping about north-north-west 50°. From Goldar to Jeshtar, and the ridge east of Saulda Peak I re-crossed over the same set of beds. I then descended towards Cheli; the latter part of the descent being entirely upon the slightly schistose slates, which in some cases became very micaceous and soft.

Gneissose granite.

Having crossed the Jumna at Barkot I took up the stream south-south-east from there, and for the first mile I passed over much the same kind of rocks, but not very schistose, the dip being irregular. Then came fragments of a granitic rock for about half a mile, though the nature of the country prevented any good exposures being seen. It appeared to be a rock related to the gneissose bed last described, but the foliation was not much marked. Then came rather gritty, close, blue-grey slates, dipping 60° west-south-west. On getting to the pass, about 6 miles from Barkot, which pass is north-52°-east from Bouk station, looking south into the tributary of the Bhagirati river there is still the gritty slate dipping 20° west-north-west. Beyond the pass, in an easterly direction, the ridge rises into a mass of the granitic rock, which also keeps to the higher parts of the spurs running down into the tributary of the Bhagirati river as far as a point east-south-east from Bouk station, where there is a sharp line of junction (probably a fault) running north-east between it and a massive blue-grey limestone. The lower parts of the same spurs are composed of the slaty rock, and some few gritty beds, with a general dip 30° or 40° west-north-west near the pass. The dip gradually veers round more to the west, and finally becomes south of west as Darng is approached. The limestone, which resembles the Deoban, only crosses the stream bed a little way, and is then cut off in another direction by a fault striking south-east almost in a direct line between Bouk station and Darng.

Returning to the granitic rock, the quartz in it is abundant, in large grains, and with no polysynthetic structure. Numerous strings of liquid cavities, and dust of opacite ramify through the quartz grains. The felspar is in the same condition as that of the Banale river gneiss. The mica is biotite as before, sometimes dark brown, but often quite black, and opaque in thin slices. The granitic mass in its upper parts seemed to change somewhat in nature and take on a rather more dioritic appearance. I was disposed at the time to think that it was indeed a gradual change in the minerals, but I had not time to stay and work all round the mountain. Specimens from the top of the ridge due east from Bouk station are almost certainly a diorite though the rock has not been sliced yet.

Continuing down the tributary of the Bhagirati near Gewla and Darng we find the same gritty slates and quartzites of dull grey colour dipping towards the south-south-west, at 45°.

It is near where the stream enters the Bhagirati that a change takes place, and the dull coloured slates and grits give way to a set of shivery slates of purple and green colours. These weather into a violet, or pale green powdery rock, which forms steep taluses on the river banks. There are some quartzite beds incorporated with them, and a few conglomerates near Upu (sheet 66). How this change sets in I did not observe, as the structure of the lower parts of the valley is much obscured by recent gravels extending up to a height of 300 feet or more on each side of the Bhagirati, and through which it has cut its course. The general dip is south-west or north-east, apparently rolling about a good deal, first in one direction and then in the other. The appearance of the beds, the nature of the conglomerate, their colouring, and especially the way they weather, forcibly reminded me of the beds seen on the road to Chakrata, near Kalsi, in Jaunsar. The whole of the fair valley of the Bhagirati down to Tiri, and probably beyond, is likewise composed as described, the uniformity being due to the recurrence of the same beds by repeated foldings.

Purple and green shivery states and quartzites.

At Tiri I left the Bhagirati river and turned east up the Bheting river, making as direct a line for Pauri as possible. As far as Nurni there does not seem to be any material change in the rocks, but looking north across the Bheting towards Kytiba and Kireh trigonometrical stations, a set of thick-bedded quartzites can be detected constituting the rugged sides and summits of those peaks. Half a mile or so north of Nurni and Koti, the same beds were traced by me running up from Ushunna along the ridge south-east and east towards Maniknath. In their lower part there is a limestone, dark blue, and resembling those already mentioned in this paper. It is only a hundred feet or so in thickness. A mile and a half east of Koti the junction between the slaty beds and the quartzite is seen on the pass leading over into the affluent of the Alaknanda river. Here, too, are some diorite and dioritic ash near the junction, and no limestone. There is also a change in the lower slaty series at this place; they lose the bright tints hitherto possessed and become more like the sombre tinted rocks that we had before entering the Bhagirati; that is to say, they are grey, and slightly schistose. They also have a nearly vertical dip south or south-west. On the left bank of the affluent, some distance above the road, the limestone and the quartzite were traced as far as Kunnali, but below this, on account of the dense vegetation of creepers, &c., nothing more could be seen of them. I should mention that this quartzite is of exactly the same type as the Bawars, a strong clear-grained quartzite, approximately horizontal, and apparently capping the heights and the ridges unconformably. It is evident, however, that having lost touch of the Bawars so long since, no reasonable correlation can be made in this case. The whole of the south-west side of the stream bed east of Chandabadni mountain down to Gar (Gur), is remarkable for the effect that the vertical or nearly vertical dip has had on the carving out of the hill-spurs: they are like a number of sharp pyramids rising one behind the other in very beautiful succession. The rest of the way to Jarkni on the Alaknanda is over the same kind of beds.

From Jarkni I crossed the Alaknanda, and arrived in British Garhwal, where I at once set to work to find a place suitable for commencing systematic mapping operations.

British Garhwal.

PART II.

It will now be useless, or at least unnecessary, to continue the narrative form of this paper. Instead, I shall endeavour to put in a somewhat brief manner the results of numerous traverses, and counter-traverses, over a geologically compact bit of country, lying north and south between the Sub-Himalayan boundary and the Nyar river, and east and west between the Ganges at Hardwar and Ghungti mountain.

This portion of the Himalaya has proved interesting geologically in two ways. In the first place, it was there that I came unexpectedly upon outliers of nummulitic and mesozoic strata, which I traced, as stated in my previous paper,[1] into conjunction with beds of the same age, long ago noticed by Mr. Medlicott as existing in the Tal and Bedasni rivers.[2] In the second place, the remarkable positions which they had assumed with reference to other rocks of the district raised momentous questions in physical geology, very much akin to what have been satisfactorily answered of late years in the Durness-Eriboll district of West Scotland.[3] These for some time proved a stumbling block to me: for, much as the solution of the Highland question tempted me to readily interpret this district by a similar line of reasoning, I felt that no real knowledge would be gained unless I could prove the case here on its own merits alone. This I have been able to do.

The small-scale map (¼ inch to the mile) accompanying this paper gives the nearly completed results of my mapping of the ground, whilst the large-scale map (1 inch to the mile) of the north-west corner of that district is the one to which I shall refer for proofs of the interpretation which I shall submit.

In my previous paper I have already indicated the petrological characters which the rocks present. With regard to their chronological order I will at once anticipate what I shall subsequently prove, by giving a table, which differs from what I previously drew up by the relative positions of the Tal (mesozoic) and the massive limestone being interchanged.

Table of formations (in descending order) in W. British Garhwal.

SUB-HIMALAYAN	Upper Tertiary	Soft, yellow, micaceous sand-rock and sandstone, few conglomerates, and purple clay bands.
NUMMULITIC	Lower Tertiary	Sombre-tinted purple and olive and grey shales, with bands of earthy limestone, containing fossils, and soft dark brown sandstone.

[1] A fossiliferous series in the Lower Himalaya of British Garhwal, Rec. G. S. I., Vol. XVIII, pt. 2, 1885.

[2] Mem. G. S. I., pt. 2 Vol. III, p. 69, 1863.

[3] See Prof. Lapworth's "Secret of the Highlands," *Geol. Mag.*, 1883. Also Messrs. Peach and Horne "On the Geology of Durness and Eriboll with special reference to the Highland controversy." *Nature*, XXXIII, 1885, p. 558.

Table of formations (in descending order) in W. British Garhwal—contd.

TAL . . .	Mesozoic . .	*Upper Tál.*—Indigo coloured calcareous grit, usually oolitic; full of broken fossils. The rock might often be called a limestone, but it is never without the sandy basis. *Lower Tál.*—Strong sandstone of millstone-grit type; quartzites, &c., few quartzose conglomerates; a black carbonaceous shale, 1 foot thick, with plant impressions, occurs in the Sour-gadh.
MASSIVE LIMESTONE	Age unknown . .	Dark, blue-grey, fairly pure limestone; thick bedded; without fossils. It resembles either the Krol or Deoban limestone.
PURPLE SLATES AND VOLCANIC BRECCIA.	Ditto . .	Slates, bedding and cleavage coinciding, usually coloured a ruddy or inky purple, but sometimes grey. The volcanic breccia is an angular clastic rock, with no rounded fragments. The material is coarse or fine, and is made up of slates, quartzites, and limestone, with very rare fragments of igneous rocks and schists.
SCHISTOSE SERIES .	Ditto . .	Phyllites, quartzites, quartz-schists, schists, and garnetiferous schists, with intrusions of gneissose granite.

Without perplexing the reader by detailing the array of difficulties which presented themselves to me at different stages of my work, I will at once come to the main difficulty, in the right understanding of which all other minor questions are bound up.

If reference is made to the ¼ inch map, the eye will at once grasp the fact that there is a central elongated area composed of the schistose series and which may be called the "Inner formation;" whilst surrounding it on all sides is a zone of all, or some, of the formations from the nummulitics down to the purple slates and volcanic breccia. These may be called the "Outer formations," in contradistinction to the schistose series. Now the belief which is at present so rapidly gaining ground that metamorphic strata are presumably older than unmetamorphosed strata makes one at the first glance assume a strong probability in favour of the inner schistose series being of much greater age than the outer zone of formations. But no sooner has this *à priori* probability obtained a firm hold of the mind than a rude shock is given to it by the discovery that at every point round the schistose area the Outer formations appear to dip towards and under the schistose series at steep angles (50°—60° generally); whilst the schistose series itself is disposed apparently in the form of an elongated quaquaversal synclinal upon the top of the Outer formations, and culminates in a capping of gneissose rock on the summit of Kalogarhi mountain (locally known as Kalan Danda), the highest point of the neighbourhood.

In other words, the observer after a hasty examination is almost driven to the conclusion that there is an upper metamorphic series lying normally upon the comparatively unmetamorphosed zone of Outer formations (a counterpart of the opinion long held with regard to the strata of the Scotch Highlands).

But in one respect the geological structure in this part of Garhwal is unique, so far as I know. The appearance of the Outer formations underlying the schistose series is not confined to one line of country, but is equally noticeable at nearly *every point round the margin* of the Inner formation, whilst up the Huil and Rausan rivers offshoots of the Outer formations appear among the schistose series, fitting in with them more like a piece of gigantic inlaid work rather than lying as unconformable outliers upon them.

When I commenced field-work last season, I was in a complete state of uncertainty as to which way to interpret the sequence of the rocks. On the one hand, I was exceedingly loth to believe that an enormous thickness of phyllites, schistose slates, schists, and even garnetiferous schists could normally belong to an era subsequent to the deposition of the ordinary slates, limestones, and sandstones of the Outer formations; whilst, on the other hand, I was equally averse to straining what then seemed to be the plain facts of the case in order to draw up a more plausible stratigraphical table. Besides, Mr. R. D. Oldham's work in Jaunsar Bawar[1] and Mr. H. B. Medlicott's[2] at Simla had already shown the extreme probability of an upper and comparatively younger schistose series normally overlying slaty and calcareous strata; and I could not of course neglect telling evidence of this kind, although so great a span of country lay between their working grounds and mine.

I was also in a state of uncertainty with regard to the Outer formations themselves; for they by no means preserved a uniform relation to one another; so much so that my first statement that the massive limestone overlaid the Tal beds has had to be discarded and reverse positions assigned to them.

The most pressing difficulty then was that of stratigraphical succession. Although the superficial relations of certain rock-series to one another had been made tolerably clear, it was not manifest which of them was really the newer, and which the older; inasmuch as sometimes they appeared in one order of superposition, and sometimes in the inverse order. In other words, the problem before me was to unravel their order of deposition in time, from conflicting appearances, due to disturbance of the strata; for, in a region of true mountains, it is not enough to see one set of beds dipping beneath another set; but in every case the question must be put—is this the normal order, or is it an inverted order?

The presence, or absence of fossils, makes all the difference in the case with which such a question is answered; though a single fossiliferous series is not sufficient by itself. But when two or more definite fossil horizons are fixed, among a set of formations roughly coinciding in dip; the sequence in time, evinced by those horizons, will necessarily proclaim the true time sequence of the whole.

Applying this principle to the comprehension of the problems before us, it was imperative to find out how the presence of the two distinct fossil horizons of the nummulitics, and the mesozoic Tal beds, in a region where the other formations are unfossiliferous, would help in settling the true order of those associated unfossiliferous rocks: whilst it was extremely probable that if the Outer formations were once chronologically arranged, a clue would be obtained which would fix the age of the schistose series. Until recently, the unfossiliferous formations had not been met with in such fortuitous conjunction with the fossil-bearing series as to enable me to

[1] Rec. G. S. I., Vol. XVI, 1883. [2] Mem. G. S. I., Vol. III, 1863.

rightly deduce their true stratigraphical order, but the time has now come when I can speak with certainty on this point, and I can throw the whole of the strata of Western British Garhwal into comprehensive groups, arranged in true historical succession (see table of formations).

Within the confines of this paper I shall merely endeavour to show how I have arrived at my conclusions, by reference to the geology represented by the accompanying maps and sections.

Referring to the 1-inch map, it will be seen that within the general curve made by the Ganges there are a set of boundaries, marked as faults, each roughly parallel to one of the reaches of the river, and, in result, giving a compound boundary somewhat resembling the course of the river. Within this boundary, except for a narrow band up the Huil river, the rocks composing the Inner formation agree in being very compact purplish quartzites, without much granular structure visible; glossy-surfaced slates, generally slightly purplish, or considerably metamorphosed into schistose slate, and schists. On the other hand, outside the boundary there are fairly regular groupings of the Outer formations, *viz.*, the nummulitics, the Tal (mesozoic), the unfossiliferous, massive, blue-grey limestone and the purple slates and volcanic breccia.

The first point to which I would call attention is that the order of superposition (whether a true order or not) of the Outer formations, up the Ganges valley, is from the purple slates and ashes below, up through the massive limestone and the Tal to the nummulitics, which are brought to a check by the boundary (see sections AA, BB). Now, in order to discover whether this order is a normal or inverted order, we must reason in this way. The nummulitics being by their fossil contents of later age than the Tal beds, which are mesozoic in age, it follows that the apparent position of the latter, dipping underneath the former, represents the true original sequence in which they were deposited. That being so, the dip of the massive limestone beneath the Tal beds must also be an original true dip; and likewise that of the purple slates and ashes beneath the limestone.

Thus, the present arrangement of the group of Outer formations, as seen near the bend of the Ganges at Lachman-jula, from the purple slates and ashes up to the nummulitics, must be the original historical one; and so part of the previous difficulty is solved once for all.

Coming now to the nature of the boundary between the Outer and Inner formations, and the question of their relative positions: it is certainly, at first sight, a most astounding coincidence that the Outer formations in nearly every locality should persistently dip towards the presumably older schistose series; especially when we have just learnt that the Outer formations, among themselves, are in a natural order. This occurrence, so marked in many places, and the lie of the Outer formations completely encircling the schistose area, make it difficult to get rid of the first impression already alluded to that the whole is a synclinal trough, with the Outer formations below, and the Inner above. One seems almost driven to conclude that if a boring were sunk through the centre of the schistose area, we should inevitably strike the Tal beds below. The very often curved direction taken by the boundary between the Outer and Inner formations, whereby it wanders irregularly, sometimes even V-ing inwards with the inequalities of hill and valley after the man-

ner of a moderate dip-plane outcrop, further enhances this belief; whilst the apparent synclinal, into which the schistose series itself is thrown, seems to clinch the matter. Indeed, if it were not for certain facts, which are at the same time pure stratigraphical accidents, and some elementary reasonings, which might be passed over, I venture to think that the above would be the natural and most plausible interpretation of the features. But nevertheless these facts, not only render the above interpretation unacceptable, but emphatically negative it; whilst I hope I shall be able to show that, owing to the exigencies of mountain structure, apparent anomalies of the above kind are certain to present themselves.

First, as to the facts: in numerous instances, as the map testifies, the Tal beds, dipping down against the schistose series, are not in direct contact with them; but there is an intermediate deposit of shales, clays, and earthy limestones of nummulitic age, which also, in like manner with the Tal, dips down against, and apparently under the schistose series from several sides. And I wish it to be understood that this statement is no general one; but the two widely distinct rocks, namely, soft shales, and highly metamorphic schists and quartzites are in *actual contact*, without any semblance of what could be called a transition rock. Thus, if the Tal beds in reality continue beneath the schistose series, the nummulitics, where present, also do the same: that is to say, a soft, shaly, tertiary rock, not only must lie as a foundation on which the schists are piled, but also must be beneath them in direct contact. To satisfy a condition of this kind the most glaring case of selective metamorphism would be totally inadequate; it results then that the schistose series must be older than, and therefore normally below the whole of the Outer series, including nummulitics, Tal, massive limestone, and the purple slates and ashes. The preservation of the thin deposits of nummulitic age may be called a stratigraphical accident, but the key it gives to the chronological order of the Outer formations, renders any other interpretation of the above impossible.

But if this is so, the false position of the Tal beds and the other Outer formations, where present, cannot be looked upon as nothing but a coincidence; there should be some inherent necessity for such a steadily anomalous position, a position of being, so to speak, tucked in all round under the margin of the inner and older formation, a necessity due, probably, to the exigencies of mountain structure. I think the following considerations will make clear what this necessity is. During the deposition of the nummulitics, the whole of that portion of the Himalaya where they now exist, must have been beneath the sea. Between then and the present time they must have been raised into a mountainous tract; and from the inclined position of these same tertiary beds we conclude that the cause which tended to raise the hills into existence was a lateral compression, acting chiefly south-west and north-east, though complicated to a certain extent by compression in other and opposite directions. Whatever be the immediate cause of this lateral compression, into a discussion of which there is no call now to enter, it is sufficient for present purposes to notice that its effect was to urge the crust of the earth to take up less horizontal space than before. This could only be brought about in two possible ways; namely, by corrugation and by faulting. That the former actually took place, we have abundant evidence; and that the latter, *viz.*, the snapping and tearing of the strata, whereby faults would be produced, also happened, we can well believe.

But if we now enquire as to what sort of faults would be produced, we shall be obliged to own that only such as could enable the strata to take up less horizontal space, in compliance with the lateral pressure, would be of any service in relieving the state of strain. From this we see that a vertical fault, having no effect of this kind, would be of rare occurrence. On the other hand, a reversed strike-fault, inclined at some angle with the vertical, would not only relieve the constant strain and bending of the rocks, but would directly contribute to the horizontal compression of the region by allowing the rocks on one side to work up over those on the other side; thus increasing the vertical thickness of the earth's crust at the expense of its horizontal extension. There being such a manifest relief accruing from such faults as these, it is but natural to suppose there would be a strong tendency to their formation. But their direct consequence is to bring about stratigraphical complexities of precisely the kind we have to deal with, by forcing older beds over the top of younger formations. On the other hand, a fault with the down throw towards the hade would obviously increase the horizontal extension of the rocks, and there could be no predominating tendency to its formation in a tract of country subject to great lateral compression. It seems, indeed, impossible to imagine them occurring in any mountainous tract, other than some few mountains due to great vertical elevation; except as dip-faults, or as secondary results due to local and intermittent relaxations.

There is thus a good *à priori* reason for expecting to find reversed strike faults, and them alone on a large scale, in the district under discussion. But that the boundary of the Tal beds with the schistose series should be so persistently a reversed fault on the dip side, an uninjured synclinal of the younger rocks scarcely ever (in only one instance that I know of) being preserved, does seem a little remarkable, until we remember that the Tal beds, save for the slight capping of nummulitics, must have been the uppermost rocks at the time when the elevation consequent on the lateral pressure began, and therefore it would only be in very favourable conditions that any trace of them would survive from the rapid denudation consequent on emergence from the sea and subsequent atmospheric waste. Simple folding would no doubt tend to bring this preservation about by allowing the anticlinal folds to be swept away whilst the synclinals were saved by being depressed below the action of the denudation agents; but it would not give results so decisive as that ultimate phase of a synclinal[1] (in combination with an anticlinal) developing a thrust plane, or reversed strike fault; whereby the Tal beds, and in some cases the nummulitics, would be actually thrust and buried under a capping of older beds; and so protected by them from all subsequent wear and tear of denudation. We are obliged to admit, from the evidence before us, that the synclinal, except in one instance, was found insufficient, and the sigma-flexure and reversed thrust plane sufficient, for their preservation; and in believing this we shall do no violence to thought, and the apparent remarkable coincidences become reasonable necessities.

A certain additional weight is given to these conclusions, when we remember that the position of the Siwalik and other upper-tertiary rocks with regard to the Outer formations, where they front the plains, is exactly what that of the Outer formations is

[1] Called a sigma-flexure, folded flexure, reflexed fold or overfold. See Heim's Atlas "Untersuchungen über den Mechanismus der Gebirgsbildung," and Lapworth's "Secret of the Highlands," *Geological Magazine*, 1883.

with regard to the schistose series. It has long since been shown by Mr. Medlicott and others that the later tertiary rocks (about the age of which there is no doubt) dip down against older Himalayan rocks, from which they are separated by a reversed fault; and there seems every reason to believe that the causes which produced this condition were simply a repetition in more recent times of a similar type of earth-movement to that which I have advocated above. In ages to come, when the Siwaliks have been worn away at their outer edge more completely by denudation, there will be left a narrow band of rocks analogous to the present reduced state of the Tal; and presenting the same phenomena of persistently dipping beneath much older beds.

It has now been proved: first, that the apparent order, among themselves, of the Outer formations near the Ganges, is their natural historical order; and, secondly, that the Inner schistose series is of older formation than the whole of the encircling Outer series.

It is satisfactory to note as a favourable issue that the complete proof now established shows that the chronological succession of the rocks as here interpreted, is a natural, and not a strained one: for, first, the more highly metamorphosed rocks are found to be the oldest; whilst decreasing age is similarly marked by a commensurate decreasing metamorphism. Secondly, the non-fossiliferous formations pose naturally as older than those which display fossils, whilst the latter, as we should expect, are together and the youngest; and, thirdly, the difficulty of the Kalogarhi gneissose mass is overcome; for since the schistose series, among which it appears, are the oldest beds, its presence whether it prove to be an archæan gneiss, which under pressure and high temperature, at extreme depths, has at some period been liquified, and so merited the name of granite; or whether it be an intrusion of subsequent date, *i.e.*, a granite in which contemporaneous or subsequent foliation has been superinduced by pressure—in either of these cases there is nothing so abnormal as to be improbable.

In this paper I have only touched on the main difficulty, ignoring for the present all less prominent questions, which a close scrutiny of the maps will suggest, *e.g.*, the unconformability of the members of the outer series amongst themselves and the marked unconformability indicated near the Sour and Kotedwar glens between the Tal beds and the schistose series. The map there shows the great thrust plane absent, and the Tal beds and nummulitics in an undisturbed synclinal. Hence the Tal beds are disposed indiscriminately on the schistose series, the purple slates, &c., and the massive limestone; a condition implying contortion and denudation such as to expose the schistose series at the time when the Tal beds were deposited. I have also refrained from going into more descriptive detail than was absolutely necessary to bring out the points of chief significance.

Above all, it seems to me that the foregoing results afford a useful lesson in enjoining the utmost caution and accuracy of mapping; in order that, amongst such intensely folded rocks, a right distinction may be drawn between ordinary dip planes and thrust planes; especially when the latter have a perfect parallelism in strike with the strike of the rocks, and hence cannot readily be recognized as differing in any way from ordinary dip planes. Extreme circumspection in this matter is a *sine quâ non* if good work is to be done in mountainous regions.

In conclusion, a few remarks may be made with regard to the connection between the district just described and other parts of Garhwal and Kumaun visited by me in the course of last season.

From the point where the east and west Nyar rivers meet, I went north-east up to the head of the east Nyar, finding nothing but the schistose series the whole way until Kainur was reached. There, the presence of more decided schists, and garnetiferous schists, heralded the incoming of more of the gneissose granite. Dudatoli, the culminating peak of the neighbourhood, like Kalogarhi in the district just described, is composed of that rock; and from it in a westerly direction extend bedded bands, strongly developed at first, but dying out gradually. All details are out of place here, as the work is still only half mapped; but I would wish to point out the exact correspondence between the gneissose granite, both in composition and in habit, here and at Kalogarhi. The only difference is, that it comes on more strongly, but at the same time more gradually: some of the first bed-like intrusions alternating with schists, as though the result of direct metamorphism. By tracing the beds laterally, however, it is seen that they die out away from the central mass of Dudatoli, and close in towards it; so that they are in reality but elongated "fingers" protruding from the Dudatoli massif.

Further north, beyond the head of the west Nyar river, we have a faulted junction, bringing in purple slates and the massive limestone along the Dobri-Danpur ridge; beyond which a thick set of diorites and quartzites make a first appearance. From here in a south-east direction towards Naini Tal we cross a similar set of formations.

One may then say (roughly generalizing) that the schistose series and gneissose granite about Ranikhet and Dwárahath are most probably representatives of like beds described in the foregoing paper; whilst the slates and massive limestone displayed about Naini Tal are, with equal probability, representatives of the purple slates and limestone also there described. It is to be noted, however, that the Tal beds, or at least the fossiliferous portion of them, are not seen near Naini Tal, and the nummulitics, though said to have been found by Messrs. Schlagintweit [1] are almost certainly absent also.

Notes on the Geology *of the* Garo Hills, *by* T. D. LATOUCHE, B.A., *Geological Survey of India.*

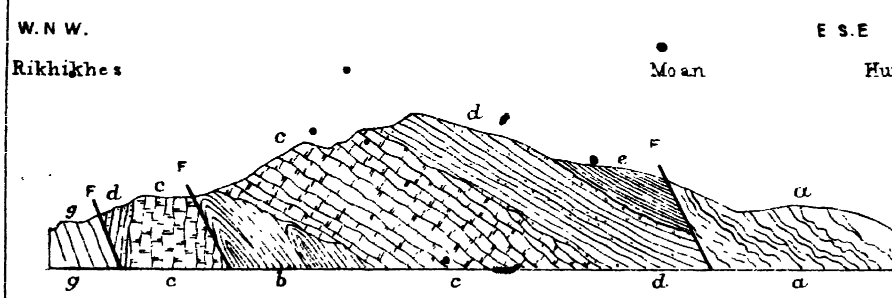
The main features of the geology of the Garo Hills have been known for several years and described in the Records and Memoirs of the Geological Survey,[2] but the valley of the Sumesary, where considerable fields of coal exist, is the only portion of the hills that has hitherto been examined in detail.[3] During the past

[1] See Manual of Geology of India, p. 609; also Journal, Asiatic Society of Bengal, Vol. XXV, p. 118.

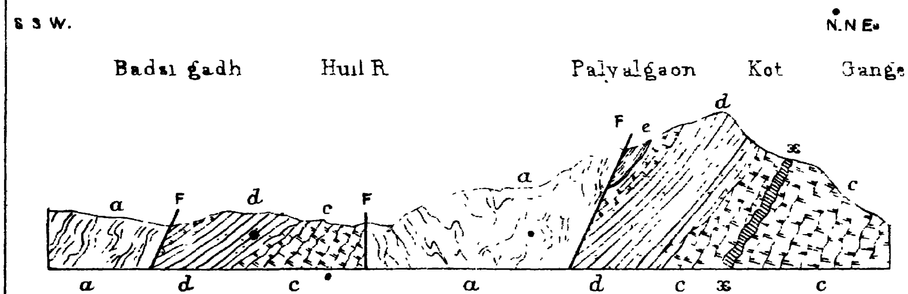
[2] Records, Vol. I, Pt. 1, p. 11. Vol. VII, Pt. 2, p. 58. Mem. G. S. I., Vol. VII, p. 151.

[3] Records, Vol. XV, Pt. 3.

Middlemiss: GEOLOGICAL SURVEY OF INDIA. Records. Vol. XX.



Section along AA.



Section along BB.

INDEX.

g Siwalik

e Nummulitic
d Tal: Mesozoic
c Massive Limestone
b Purple slates &c

} Outer Formations.

a. Schistese Series — Inner Formation.

x. Diorite

F Fault.

AMINULLAH

PART OF BRITISH GARHWAL SECTIONS. *See the 1=inch Map.*

field season I commenced a systematic survey of the hills, starting from the already described sections on the Sumesary, and working westwards along the southern base of the main range of gneiss, which runs in a west-north-west direction through the centre of the district.

The formations represented in the Garo Hills are the following :—Gneiss, cretaceous sandstones with coal, nummulitic limestone with associated sandstones, and upper tertiary sandstones. A still more recent formation, consisting of terraces of gravel and boulders at a considerable elevation above the existing river courses, is extensively exposed in the south-western portion of the district, but I have not had many opportunities as yet of examining it.

In the adjoining Khasia Hills other formations intervene between the gneiss and the cretaceous rocks, *viz.*, the Shillong series, the Khasia trap and granite and the Sylhet bedded traps. Numerous dykes of a fine grained compact trap do occur intrusive in the gneiss of the Garo Hills, which may possibly represent some of the igneous rocks of the Khasia Hills, but in that case one would expect to find similar dykes intrusive in the Khasia Hill gneiss, and as far as I know they do not occur in it. The dykes in the Garo Hills are pretty generally distributed throughout the district, but are most numerous in the north-western portion of the hills, where it is rare to find a section of the gneiss without coming upon one or more of these dykes. They are generally narrow and coincident, or nearly so, with the strike of the gneiss, but sometimes appear to have been intruded horizontally along joint planes, and often show well defined columnar jointing perpendicular to the surfaces of contact. In many places where sections are not available these dykes betray their presence by the numerous rounded exfoliating blocks of greenstone, derived from the breaking up and weathering of the columns, which are scattered over the surface of the ground.

The cretaceous rocks, which rest immediately upon the gneiss, have hitherto received the greatest amount of attention in this district, because in some places they contain good seams of coal. The only workable seams, however, seem to be confined to the valley of the Sumesary and the country to the east of it, in which direction they extend to the Langrin coal-field in the south-west Khasia Hills. At the village of Aruak, only a few miles to the west of Siju on the Sumesary (where coal of good quality occurs), a considerable thickness of cretaceous rocks is exposed, resting nearly vertically against the gneiss, without a trace of coal. Still further to the west, on the head waters of the Nitai and Bogai rivers, the cretaceous rocks rest horizontally on a platform of gneiss, from 4 to 5 miles broad, which extends for about 14 miles along the base of the main range. Numerous sections are exposed in the river gorges, the total thickness of the sandstones being from 500 to 600 feet, but in no case did I find any trace of coal. At the southern edge of this platform of gneiss the cretaceous rocks bend over and quickly disappear beneath the nummulitic limestone and newer rocks. Further still to the west, below Tura, and on the Singmari plateau, the few exposures of coaly matter that do occur were long ago shown to be worthless. The question whether this coal improves towards the deep, which can only be ascertained by boring, still remains undecided; though from the fact mentioned above of its disappearance west of the Sumesary, it is not likely that such would be the case.

A white shaly indurated clay, or lithomarge, occurs in most places where the cretaceous rocks are exposed, in bands of 2 or 3 feet in thickness; when better communications through the hills are opened out, it may prove to be of some value as a pottery clay. There is a thick deposit of it in the station of Tura; where it has been used for white-wash. At present the Garos obtain the material they require for their rude pottery from beds of a stiff yellow clay which occurs locally immediately above the nummulitic limestone.

Conformably overlying the cretaceous sandstones is a series consisting of nummulitic limestone and fossiliferous sandstones with sandy shales. The main band of limestone always occurs at the base of the series, thin bands of limestone also occurring in places in the sandstones above. The thinning out of the limestone between the Sumesary and Damalgiri Thana, where in 1868 Mr. Medlicott noticed the western extremity of the bed in a thin band of rusty concretionary limestone, is very marked, as well as its rapid deterioration in quality. About 150 feet of it are exposed in the Bogai at Ganchi, but the whole is sandy earthy and nodular. The sandstones which overlie the limestone are fine grained, ferruginous, and generally show a tendency to become nodular. In these rocks fossils had previously been found only in one locality, *viz.*, on Nongkulang hill in the south-west corner of the Khasia Hills, where Colonel Godwin Austen collected a large number of specimens from sandstones immediately overlying the nummulitic limestone.[1] These were examined by Dr. Stoliczka, who remarked that none of the species appeared to be identical with those known from the nummulitic rocks of the district. Unfortunately there are very few of Colonel Godwin Austen's specimens in the museum, nor do any of them appear to be those examined by Stoliczka, while no description of the fossils from the nummulitic limestone of these hills has been published; so that I have been obliged to compare my specimens with those described in D'Archiac and Haime's nummulitic fauna of Sind, and with European species. Among them I have been able to identify the following with more or less certainty:—

From the cart road between Tura and Mankarchar, about 7½ miles from Tura—

Cardium greenoughi.	Corbulomya triangula.
Cytherea orbicularis.	Venus nucleus.

From scarp west of Warimagiri village (marked Warogiri on map)—

Arca subfiligrana.	Fusus, ? javanus.
„ sabuletorum.	Fusus aciculatus.
Cardium tenuisulcatum.	Conus sp.
„ austeni.	Ampullaria pygmæa.
„ anomale.	? Mitra sp.
„ sp.	Solarium sp.
Cyrena distincta.	? Achatina fragilis.
Nucula sp.	Cassis sp.
Ficula pannus.	Turbinolia.

From the Kilburn stream near Khenigiri village—

Mactra sp.	Crassatella propinqua.
Lima bulloides.	Rostellaria lucida.
Turritella granulosa.	

[1] Jour. As. Soc. Bengal, Vol. XXXVIII, Pt. 2.

From about 1 mile east of Khenigiri village—

Cardium multisquamatum.	Cytherea sp.
Cardita subcomplanata.	Crassatella sulcata.
Isocardia sp.	Pecten decussatus.
Cypricardia sp.	Rostellaria lucida.
Arca capillacea.	Natica sp.
Venus sp.	? Balanophyllia

From scarp east of Bogai river near Ganchi—

Rostrum of Balanus.

From ridge between Damakchi and Rongpha streams near Duching village—

Crassatella bronnii.	Cyrena sp.
Cytherea orbicularis.	Pecten sp.
,, obsoleta.	Rostrum of Balanus.
Lucina sp.	

The above species are nearly all found in the eocene deposits of Europe. All the fossils occur as casts in fine sandstone, the original shell being in no case preserved, so that it is often difficult to make out the specific characters. The specimens found at Nongkulang hill by Colonel Godwin Austen belong to the genera *Conus, Dolium, Dentalium, Cardita, Cardium, Tellina, Nucula, Leda, Cucullœa,* &c.,[1] but the names of none of the species are given. There is little doubt however that these fossiliferous sandstones should be classed as nummulitic owing to the thin bands of limestone containing minute nummulites, which are intercalated with them. One of these beds (in the Mandar stream, about 3 miles west of Emangiri) which is well up from the bottom limestone band, contains numerous specimens of *Operculina canalifera*, a species very common in the nummulitic limestone of Cherra.

The fossiliferous sandstones pass up into a mass of very similar sandstones, which attain a thickness of about 1,200 feet in Joksongram hill near Shushung Durgapur. In these no fossils have as yet been found, partly, I believe, owing to the coarseness of the sandstones, some of them being almost conglomerates and not suited to the preservation of casts. I am hopeful, however, that further search will reveal the presence of fossils in these rocks, without which their separation from the underlying nummulitics will be a matter of great difficulty.

Note on some Indian image-stones, *by* COLONEL C. A. McMAHON, F.G.S.

Gaya (Gya): Nos. 7—200. 7—201. 7—202. 7—203. 7—205.

The specimens were sent to me by Mr. Medlicott, Director of the Geological Survey, and I have given the Survey register numbers for facility of reference.

Gaya is a very sacred place both for Hindus and Buddhists, and this stone is extensively worked into images and utensils of various kinds for traffic with the pil-

[1] Mem. G. S. I., Vol. VII, Pt. 3, p. 9 note.

grims. A reference to its mode of occurrence in the field will be found in Vol. II of the Records of the Geological Survey, page 42.

M.—These samples are all so similar one to another under the microscope, that a general description of them is all that is requisite. The matrix of the rock appears to be quartz, though free quartz is not prominent in all the slices. It is abundant in No. 201, but is almost absent in No. 205. The quartz is very pure and limpid, and contains no liquid cavities.

The most prominent feature in the rock, perhaps, is the abundance of chlorite and sericite which it contains; the two minerals being intimately mixed up with each other. Under the microscope sericite in several respects much resembles talc; but some of the colourless, foliated, mineral seen in the field of the microscope is certainly a mica, and from the amount of water small pieces of the rock yield in a glass tube under the blow pipe, I think it is safe to assume that the whole of it is sericite. Indeed, the flame of a spirit lamp, without a blow-pipe, supplies sufficient heat to make the rock give up water abundantly. No. 205 is highly micaceous in its macroscopic aspect.

Felspar, all of which belongs to the triclinic system, is also a prominent feature in the rock taken as a whole. It is entirely wanting in my slice of No. 205 (in which free quartz is also extremely sparse), and it is very subordinate to the quartz in No. 201; but it is present rather abundantly in the other slices. In No. 203 it occurs in sufficiently large, and sufficiently numerous crystals, to impart a speckled appearance to the hand-specimen. It is beautifully twinned in single crystals, or in groups of crystals; but in no case does it exhibit any external crystallographic outline, being, for the most part, in more or less rounded nodules. Magnetite or ilmenite, apparently the latter, is present in all the slices, except, No. 205, where it has been converted into a substance resembling leucoxene. The iron contains numerous inclusions, or intergrowths, of chlorite.

Some of the slices contain a few micro-garnets; No. 201 contains a very little schorl, and No. 203 a minute sphene.

The rock appears to be of metamorphic origin. Nos. 201 and 203 have, macroscopically considered, a specially trappoidal appearance; but the rock presents nothing under the microscope to suggest an igneous origin. The quartz is not like the quartz of granite, or its allies; and the rounded character of the felspar crystals appears to me to be due to segregation having taken place in an imperfectly plastic mass, and not to have had its origin in the solvent action of an igneous matrix. The felspar contains no inclusions of the matrix.

Dhalbhum: E. 30.—A light grey coloured rock, slightly soapy to the feel, and of more "cheesy" type, than the previously described specimens. Under the microscope it is seen to be composed of chlorite, a micaceous-talcose mineral that may be either a hydro-mica (sericite) or talc, magnetite, sphene, and calcite; the latter is not inconsiderable in amount. This is a more orthodox potstone. In his Geology of Manbhum and Singhbhum[1] (of which latter district Dhalbhum is a sub-division) Mr. Ball mentions eight localities where this rock has been extensively worked. It occurs in thick beds in the 'sub-metamorphic series.'

Gaur: Nos. 7—244 and 7—246.—Principally used for carved work in the ruined

[1] Memoirs Geol. Sur. Ind., Vol. XVIII, p. 148.

buildings of Gaur, in the Maldah District, the ancient capital of Bengal; but the actual specimens are from the famous Adina mosque, at Panduah, 20 miles north-east of Gaur. It is not known where the stone used for these buildings was quarried. The ruins are in the delta of the Ganges, and the nearest (25 miles) rocks are the Rajmahal traps, beyond the Ganges. In appearance Nos. 244, 246 look like argillites, but they do not greatly differ in macroscopic aspect from some of the Gya potstones. They might pass for very fine grained varieties of No. 7—202.

Nos. 7—244 and 7—246 consist of very minute grains of quartz averaging about one thousandth part of an inch in diameter (the largest is under three thousandths of an inch in diameter), and minute fibres of mica (probably a hydro-mica) set in a structureless base that represents, I apprehend, the original setting of fine mud. In this ground mass, there are starred about skeleton prisms—ghost-like forms, without bones or substance—of what may possibly be the spirits of hornblende in the hades of metamorphism. They have no action on polarised light; their ends are unfinished; and in neither of my slices are cross-sections of the prisms to be obtained. Indeed, they have so little substance about them that they have not displaced, or assimilated, the quartz grains of the matrix which show sharp and clear within them, and have been wholly undisturbed by the formation of the prisms. Evidently their genesis has been due to segregative action. These crystals are of dark greenish colour in transmitted light; but they are without internal structure and exhibit no dichroism. It is impossible to give them any definite mineralogical name.

On applying high powers these slices are seen to contain very numerous micro-sphenes from one to one-and-a-half thousandths of an inch in length. The quartz grains are sub-angular—none are distinctly rounded. The fibres of mica all point in the same general direction, but the rock does not present any distinct lamination.

This argillite may possibly come from some sedimentary beds intercalated with the Rajmahal traps (I am personally ignorant of the locality), but there is nothing in the structure of the argillite to indicate any connection with it and the trap. In composition, too, it is seen under the microscope to be different from the Gaya potstones. The latter are essentially micaceous-chloritic-schistose rocks, or talcose-micaceous-chloritic rocks. The Gaur stones are fine grained sandy argillites. Both are metamorphic sedimentary rocks. The Gaur rock is an interesting one to the student of metamorphism.[1]

In the Gaya potstones I have felt considerable difficulty in discriminating between hydro-micas and talc. Some of these rocks undoubtedly contain mica; a silvery mica, for instance, is very prominent in No. 7—205, even when viewed macroscopically; but it is, I think, in the present state of our knowledge, impossible to say from optical evidence whether the micaceous-talcose mineral present in these rocks is a hydro-mica (presumably sericite) or talc. M. M. Fouqué and Michel Lévy in their *Minéralogie Micrographique* give some useful hints for discriminating between sericite and talc, but I have not found them sufficient to enable me to satisfy my mind in this case, though I have bestowed considerable labour on the subject.

[1] Colonel McMahon's decision that this Gaur stone is not trappean, increases the difficulty as to whence it can have been derived. The known intertrappean beds of the Rajmahal hills are utterly different from this stone, and always exhibit distinctly their sedimentary origin; so, if not igneous, the Gaur stone can hardly have come from that ground, and all other rocks *in situ* are very distant.—H. B. M.

On Soundings *recently taken off* Barren Island *and* Narcondam, *by* COMMANDER A. CARPENTER, R.N., *H. M. I. M. S. 'Investigator,' the Officer in charge of the Marine Survey of India.*

In February 1884, the volcanoes of Barren Island and Narcondam, in the Bay of Bengal, were surveyed topographically and geologically by Captain J. R. Hobday and the undersigned, the results of our work being published in the Memoirs of the Geological Survey of India (Vol. XXI). In the report alluded to I pointed out[1] that scarcely any reliable soundings had been taken off the shores, and that, although there was reason to believe that the volcanoes rose from very deep water, almost nothing was known on this point with certainty. The projected scientific cruise of H. M. I. M. S. *Investigator* seeming to afford a possible opportunity for examining the ground, I drew up a short note respecting the desideratum in question, which was forwarded by the Director of the Geological Survey to Captain A. Carpenter, the Officer in charge of the Marine Survey of India, in command of the *Investigator*. Our acknowledgments are due to him for the readiness with which he fell in with the suggestion offered, and for the charts, of which reduced copies are appended herewith, giving the results of soundings taken by him last May.

The following sections have been plotted from the above soundings, combined with the sub-aerial contours as given by Captain Hobday.

In respect to Barren Island, especially, they show very clearly how insignificant the visible portion of the volcano is, in comparison with the huge mass of ejecta which has been piled up beneath the waves. The volcano certainly rises from a depth of not less than some 800 fathoms, giving a total height from the sea-bottom of not less than 6,000 feet, as the volcano stands at present, or some 8,000 before the upper part of the outer cone was blown away.[2] But the outward slope is still continued at the deepest soundings taken, indicating that the base of the sub-marine mountain (or the sea-floor) must be sought still further out, and that the entire altitude is still greater than that given.[3]

Most sections of the inner cone present an angle of 32°, while the average slope of the outer cone above water has been estimated at about 25°.[4] Of the sub-marine slopes plotted B has, near the shore (*i.e.* inside the first sounding), the remarkably steep inclination of $32\frac{1}{2}°$, the sub-aerial slope above being only 21°. At C the corresponding inclinations are nearly equal, or 28° and $30\frac{1}{2}°$. A shelves more gradually, or at 19°, which may perhaps be attributed to the latest outpour of lava through the breach into the sea.[5] D is not steeper near the shore than considerably further out.

Taking the entire lines of sounding into consideration the mean inclinations for equal distances are fairly uniform with one exception. Thus the inclinations of A,

[1] Memoirs, Geol. Surv. of India, Vol. XXI, pp. 258, 281.

[2] *Ibid*, p. 257.

[3] Since the above was written, later soundings, given in the letter published below, have been received from Captain Carpenter, which indicate a probable total height of some 8,000 ft., at present, and 10,000 formerly.

[4] *Op. cit.* 257.

[5] *Vide* Map, *Op. cit.*

B, and C for the first $2\frac{1}{4}$ miles from shore (the total length of the shortest line B) are respectively $16\frac{1}{2}°$, $18\frac{1}{2}°$ and $20\frac{1}{2}°$.

The reason why the water is comparatively shallow to S.S.W. of the volcano (along the line D) is not very apparent. Any effect caused by the action of the wind, during the eruption of fragmentary ejecta, would be sought for on the opposite side of the island, *i.e.* to leeward of the south-west monsoon.[1] According to the charts of the Bay of Bengal, just issued by the Meteorological Department, the currents are very irregular in that part of Bay, so that the effect in question can scarcely be attributed to a persistent set of detrital material in one direction. The shallow water is in the continuation of the line joining Narcondam and Barren Island, a fact which lends some little support to the idea that one or more sub-marine eruptions have occurred there; but in this case one would expect a more irregular sea-bottom than the soundings indicate. It may be, indeed, that eruptions of ash, &c., have occurred as suggested, and that the material has been distributed over the surface by the action of currents.

Both sections of Barren Island show along the sub-marine slopes that curvature of outline, due to gradually decreasing inclination, which is so common in sub-aerial volcanoes, and of which an admirable example is to be found in the great Japanese volcano of Fusiyama.

Samples of the material brought up by the lead from nine of the soundings[2] (including the deepest and furthest out) were sent to the Museum by Captain Carpenter. The stony matter consisted in every case of grains and small pellets of black volcanic ash. With reference to organisms Captain Carpenter writes—"I consider that there was a remarkable paucity of marine foraminifera deposit *over* the volcanic or pluvial detritus in the depths round Narcondam Island, and a complete absence round Barren Island for many miles, which appears to show the slowness with which marine deposits are made in that portion of the ocean. You will notice on the tracings of our soundings that I have noted the occurrence of globigerina and pteropod shells round Narcondam, but only in three cases was the major part of the formation composed of marine ooze." That there should be more organic deposit on the sea-bottom off the shores of an extinct volcano, like

[1] *Op. cit.*, p. 255.

[2] The soundings in question were:—

Point to which bearing was taken.	Magnetic bearing.	Depth in fathoms.	Surface Temp. of Sea.	Temp. at bottom of Sea.
Cone	S. 76° 30′ E.	855		
Ditto	S. 78° 45′ E.	644	85°·8 F.	43°·0 F.
Ditto	S. 76° 50′ E.	456		
Peak, 1,025 ft. . . .	N. 64° 45′ W.	433		
Ditto	N. 67° 45′ W.	641		
Cone	S. 12° 55′ W.	782	...	41°·8 F.
Peak, 1,032 ft. . . .	N. 33° 10′ E.	299		
Ditto	N. 31° 28′ E.	413		
Cone	S. 21° 51′ E.	325		

The surface temperatures at two other soundings were 86°·0 and 86°·5. The temperatures given above are corrected for pressure.

Narcondam, than round an active one like Barren Island, is what might perhaps be expected. Such deposits in the latter case are always liable to be buried beneath showers of ash.[1]

It will be noticed that the soundings off Narcondam are on the whole shallower than those round Barren Island. To a certain, but probably to only a small, extent this may be due to the raising of the sea-bottom through the wash of detritus off the flanks of the extinct volcano.

It would seem, however, that the minimum depth assignable to the sea-floor cannot be less than some 600 fathoms, which would give a total height to the volcano of about 6,000 feet.

F. R. MALLET.

Since the above was written, the subjoined interesting letter, from Captain Carpenter, dated 22nd November, has been received.

"In continuation of my letter No. 903 of 1st November 1886, I have to acquaint you that on passage to Burma this month I took deeper soundings between Barren Island and Narcondam Island, obtaining these casts :—

Fathoms.	Miles.		
1,140	25½	N.	of Barren Island
1,010	24½	S.S.W. of	Narcondam.
362	9½	N.N.E. of	do.
290	16	N.N.E. of	do.
70	52	N.N.E. of	do.

On the tracing sent you last July there is a cast of 411 fathoms at 4½ miles N.N.E. of Narcondam; and on the published charts there is about 50 fathoms at 70 miles N.N.E. of it, from which the depths shoal gradually to the delta of the Irrawaddy. It therefore appears that the deltaic shelf extends right out to Narcondam.

A thermometer sent to the bottom at the 1,010 fathoms cast shewed 41°·2 corrected temperature Fahrenheit. The usual temperature of the Bay of Bengal at 1,010 fathoms is 37°·6, and the temperature 41°·2 is that suitable to a depth of 740 fathoms. If we look at a chart of the east side of the Bay of Bengal we see that there are three inlets into this partly enclosed sea. One is only 150 fathoms deep, *viz.*, Preparis Channel; one is not marked with any depth, *viz.*, the Ten degrees channel; and one has 760 fathoms marked nearly on the ridge between Acheen Head and Great Nicobar.

As you are doubtless aware, the cold of the great ocean depths is due to the gradual flow of Arctic and Antarctic waters towards the equator, and it has been shown by the *Challenger* expedition that where the cold flow rises to pass over a ridge it becomes warmed, and does not again lose its heat on descent into a deeper bed.

This temperature then at 1,010 fathoms, equal to the normal temperature at 740 fathoms, seems to prove, as far as one observation can be a proof, that no greater depth than 740 fathoms exists on the ridges between Acheen Head and Great Nicobar, nor in the Ten degrees channel."

[1] While on the subject of Barren Island, I should mention that Mr. Daley, Apothecary of the *Investigator*, landed on the 28th April, and noted the temperature of the hot spring as 110° F. This is interesting as showing that the decrease of temperature which has been going on during the last quarter of a century (Mem. Geol. Surv. of India, XXI, 275) still continues. Captain Carpenter remarked that "from the ship the thin column of steam (from the central cone) could be barely seen at 3 miles distance."

Note on a character of the Talchir boulder beds, *by* W. T. BLANFORD, F.R.S.

There is a character of the Talchir boulder bed to which I do not think attention has been called, but which appears to me to throw some light on the origin of the deposit. This is the combination of large size with thorough rounding of the boulders.

In many places boulders exceeding a foot in diameter are as common as smaller fragments, sometimes, if my memory is correct, more abundant, whilst thoroughly rounded masses of 2 and 3 feet in diameter are of frequent occurrence, and even larger rounded boulders may be found. I have measured more than one 6 feet in extreme length. The boulders are often almost, or quite, spheroidal in shape, evidently from the effect of being rolled.

Now rolled boulders of this size, exceeding a foot in diameter, are, I believe, of extremely rare occurrence on sea coasts. I have not for many years had an opportunity of visiting a stormy coast composed of hard rocks, but so far as I can learn from enquiry large rounded boulders are not often met with in any quantity. In large rivers such rounded masses are also infrequent, and are only found in very rapid streams, such as the Nerbudda. When they do occur, they are few in number, compared with the smaller pebbles. Large rounded blocks with but few associated smaller fragments are, so far as my experience serves, characteristic of hill or mountain torrents.

I may be mistaken on these points, but I think the question is worth raising. If I am correct it seems probable that the Talchir boulders are derived from rapid streams. The beds themselves however in their fine texture and general absence of false bedding indicate deposition from still or slowly moving water. My impression is that they were formed in large marshes or lake-like expansions of great river valleys. The utter unconformity between the Talchirs and all underlying formations indicates a great change in the condition of the country at the commencement of the Gondwána period, a change by which an area of subaerial denudation was converted into one of partial deposition. If the change, as is probable, was one diminishing the fall in the river valleys, a natural result would be that in portions of those valleys there would still be a sensible though diminished fall, whilst other parts would be converted into large marshes or shallow lakes. In the latter the Talchirs may have been deposited, the boulders being floated in from stream beds in the surrrounding hills. The only known agent in floating such boulders is winter ice, especially when broken up by floods in spring; water weeds and roots of trees could not account for the number and frequent occurrence of the boulders in so many different places. The circumstance that the boulders are of irregular occurrence, abundant in places, in others absent, is quite in accordance with the theory put forward.

It should be understood that the Talchir beds to which I refer in this note are those of Bengal and the Central Provinces generally. Mr. R. D. Oldham has recently shown that the boulder beds noticed by myself some years ago in Western Rajputana are also probably Talchirs, but I quite agree with him that these differ from the typical deposits in several respects.

Analysis of Phosphatic Nodules *from the* Salt-range, *Punjab, by* H. WARTH, PH.D.

The analysis shows the following composition :—

Insoluble silica, &c.	4
Phosphorus pentoxide	30
Carbon dioxide	4
Sulphur trioxide	2
Chlorine	trace.
Aluminium	"
Ferrous oxide	2
Magnesium oxide	2
Balance—Calcium oxide, water, organic matter and loss	56
	100

The proportion of phosphorus-pentoxide is equivalent to 66 per cent. of ordinary pure calcium phosphate.

These nodules occur in the shales above the coal in the eocene strata of the Eastern Salt Range in the Punjab.

They are covered all over with peculiar circular pores. Very often shells are also found metamorphosed into the same phosphatic mineral.

The nodules are very numerous about Dandot Colliery and the neighbourhood. The quantity of material (as far as it was followed up) was not found sufficient for practical utilisation, but the occurrence is so far of interest as it affords another proof of the presence of phosphatic mineral in the sedimentary strata of India.

ADDENDUM ET ERRATUM.

Page 66.—The eocene chelonian *Hemicnelys* is entirely devoid of epidermal plates, and may be referred to the same family (*Carettochelydidæ*) as the existing *Carettochelys* of New Guinea. The larger chelonian from the same deposits belongs to the South American genus *Podocnemis*.

„ 71.—*Ceratodus* has been found in a fossil state from the permian to the cretaceous.

R. L.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1887. [May.

The Fossil Vertebrata *of* India, *by* R. LYDEKKER, B.A., F.G.S., &c.

INTRODUCTORY.

In the 'Journal of the Asiatic Society of Bengal' for the year 1880 there appeared a paper by the writer under the title of a 'Sketch of the History of the Fossil Vertebrata of India,' in which every species of fossil vertebrate then recorded from India was mentioned; while there was also given a short summary of the labours of those palæontologists who had written on the same subject. The same paper was republished in a more expanded form in the 'Records' for 1883, bringing up the information to that date. Since the publication of the latter paper owing to the completion of the description of the Siwalik and Gondwana vertebrates a great increase in our knowledge of the subject has been obtained, and it has accordingly been thought advisable to republish its substance, with such additions and alterations as are necessary to bring it up to the present time. In many instances these alterations have been so extensive as to have made it necessary to rewrite a great portion of the paper. As in the previous issue, it has been thought better to omit the introductory portion of the original paper, in which the names of the chief workers in this field of enquiry are recorded, as there is no essential alteration to be made regarding them. Some introductory observations on the general relations of the Indian fossil vertebrates have likewise been omitted, as well as all the references: the nomenclature employed has been amended in many instances.

The plan of the original paper has been in the main adhered to; but the order in which the classes of the Vertebrata are taken has been reversed, and their history is traced from the newest to the oldest horizons, instead of from the oldest to the present time. At the end a systematic synopsis of all the known forms is given, arranged according to their geological distribution. The great majority of the species will be found described or noticed either in the 'Palæontologia Indica,' or in the writer's 'Catalogue of the Fossil Mammalia in the British Museum.' Synonyms have been in most cases omitted.

It is hoped that this brief summary will enable the reader to grasp the chief features of the past vetebrate life of India without the trouble of wading through the somewhat bulky literature in which its history is more fully recorded.

CLASS I.—MAMMALIA.

Pleistocene and later deposits.—The mammals of the pleistocene and later deposits are generally but imperfectly known, although the Karnul caves have yielded very important information in regard to those of Southern India. As the pleistocene ossiferous strata are distributed in patches, very frequently in the valleys of the great rivers, the remains from the more important of these areas must be treated of separately. The most important localities are the caves of Karnul; other parts of Madras and the Deccan; and the valleys of the Jamna, Narbada, Pemganga, Kistna, and Godavari, with their numerous tributaries. It is moreover not improbable that the topmost strata of the Sub-Himalayan Siwaliks should also be referred to the pleistocene. In many instances, as in the delta of the Ganges, it is difficult, if not impossible, to draw any satisfactory line of distinction between the pleistocene and the prehistoric deposits, and the two are accordingly considered together. The presence in any stratum of the remains of *Hippopotamus*, or other genus not now found living in India, is considered as fair evidence for assigning such deposit to the pleistocene.

Human remains and neolithic implements have been obtained in the alluvium of the plains in many localities, and frequently at considerable distances below the surface; the former are generally very imperfectly preserved and have never been carefully examined. Polished celts are abundant in many places, particularly in Burma and the Banda district of the North-West Provinces. The prevailing types are elongated forms with oval section, wedges, and the 'shouldered' form. Among the mammals, specimens of the teeth and jaws of a *Macacus* from the alluvium of Goalpara, in Assam, may belong to *M. sinicus*, while others from Madras have been provisionally referred to *M. rhesus*. Molars of the Indian elephant occur in the alluvium of the plains. A last upper molar of *Rhinoceros unicornis*, in the Indian Museum, was obtained from a turbary in Madras, and indicates the former extensive range of this species; and it may be observed in passing that the range of other species of the genus was probably more extensive than at present, even in the historic period, since it has been inferred that the species hunted by Akbar on the banks of the Indus was *R. sondaicus;* this inference being founded on the improbability of its being possible to kill *R. unicornis* by means of arrows, with which Akbar's animals were destroyed. *Sus cristatus* has also been obtained from the turbaries of Madras and Calcutta. Antlers, horn-cores, and teeth of undetermined species of *Bos* or *Bubalus* and *Cervus* have been obtained from the alluvium of various districts in the plains, and from raised beaches in Kattiawar. The mammalian fauna of the caves in the Karnul district of Madras besides including a large number of species still found living in India, which are mentioned in the list given in the sequel, also comprises a species of *Cynocephalus; Hyæna crocuta* of South Africa; a small *Viverra* termed *V. karnuliensis*, which presents characters connecting it with the Siwalik *V. bakeri;* the African *Equus asinus;* a larger undetermined species of the same genus; an atelodine rhinoceros named *R. karnuliensis*, apparently allied both to *R. etruscus* and *R. bicornis;* a large undetermined antelope; a peculiar species of large *Sus* named *S. karnuliensis*, which is apparently intermediate between *S. cristatus* and the Siwalik *S. falconeri;* a *Hystrix* named *H. crassidens;*

a species of *Atherura* (*A. karnuliensis*); and the large *Manis gigantea*, which is now confined to Western Africa. The peculiar Indian genera *Boselaphus* and *Tetraceros* are represented by the existing species; and the fauna as a whole is remarkable for the mingling of African and modern Indian forms, and also for its connecting the existing fauna of the country with that of the Siwaliks, which likewise presents a remarkably Ethiopian facies, as is exemplified by the presence of *Troglodytes*, *Cynocephalus*, *Hippotragus*, *Cobus*, *Alcelaphus*, *Giraffa*, *Hippopotamus*, *Struthio*, &c. Human remains occur in the caves among those of the extinct mammals.

From the laterite of Madras palæolithic implements and a human platycnemic tibia have been obtained.

From the alluvium of the Kistna valley, in the Deccan, a part of the skull and mandible of a rhinoceros has been described under the name of *Rhinoceros deccanensis*. This species belongs to that section of the atelodine group having molars of the Sumatran type, and is characterised by the strong cingulum on the upper premolars. Remains of a bovine, which is not improbably *Bos namadicus*, have also been obtained from the same deposits, and, with the last-mentioned specimens, are in the Indian Museum.

From the ossiferous gravels of the Narbada palæolithic implements of a rude form have been found associated with bones of extinct Mammalia. The Carnivora are represented by a small species of bear (*Ursus namadicus*), of which there are a maxilla and a tibia in the British, and a canine in the Indian Museum; while a large species of *Felis* is indicated by the distal extremity of a femur in the former collection. Of the Proboscidea, there is *Elephas namadicus*, characterised by its prominent frontal ridge, whose molars very closely resemble those of the European *E. antiquus*. There is one fine cranium in the British Museum, and there are three other crania in the Indian Museum. The stegodont group of the genus is represented by *E. ganesa*, of which there is a fine tusk in the Indian Museum; and very probably by *E. insignis*. The Perissodactyla are represented by *Rhinoceros unicornis* of which the Indian Museum has two molars; and by a little-known and apparently extinct form to which the name *R. namadicus* has been applied; there is a scapula of this species in the last-named collection. There is also a species of horse (*Equus namadicus*) which seems to be a survivor from the Siwaliks, and is allied to the existing species of the genus. Among the Artiodactyla three species of bovine animals have been described, *viz*., *Bos namadicus*, a species showing some affinity to the Asiatic group *Bibos*, of which there is a magnificent skull in the Indian Museum; a *Bubalus* now identified with the existing *B. buffelus*, but formerly regarded as distinct and named *B. palæindicus*; and *Leptobos fraseri*, which is sometimes hornless, and is represented by some fine skulls in the British Museum. A species of nilghai, of which there are two broken crania in the same collection, has been named *Boselaphus namadicus*; it is distinguished from the living species, among other characters, by the horns being placed nearer to the orbits. The deer are represented by *Cervus aristotelis*, *C. porcinus*, and perhaps *C. duvaucelli*. The existing *Sus cristatus* makes its first appearance in these beds, which also contain two species of *Hippopotamus*, in one of which (*H. namadicus*) there are three pairs of small incisors, while in the other (*H. palæindicus*) there are two pairs of large incisors, but the second pair are reduced to very small dimensions, and may have been absent in the

adult. Some incisors in the Indian Museum indicate the presence of an undetermined genus of murine rodent.

From the pleistocene of the Jamna valley only four mammals have been specifically determined with any certainty, *viz.*, *Elephas namadicus*, *Bubalus buffelus*, *Hippopotamus palæindicus*, and the living *Antilope cervicapra;* the latter being known by a horn-core in the Indian Museum. In addition to these, remains of a species of *Semnopithecus*, *Sus*, *Boselaphus*, *Equus*, *Mus* (?), and of a *Rhinoceros* furnished with lower canines, have also been obtained. A *Felis* as large as the existing tiger is indicated by a scapholunar bone in the Indian Museum: this species was very probably the same as the Narbada form, and may have been either *Felis tigris* or *F. leo.*

The pleistocene of the Pemganga valley has yielded remains of *Bos namadicus*, a *Boselaphus*, and *Hippopotamus palæindicus*.

The remains from the Godavari deposits have not yet been satisfactorily determined.

Pliocene—The horizontal lacustrine strata of Hundes in Tibet, which are provisionally regarded as of pliocene age,[1] have yielded a small number of mammalian remains, among which is a tooth referred to a species of *Hyæna.* Bones belonging to some form of horse have also been obtained, among which a cannon-bone in the collection of the Geological Society indicates a species of *Hipparion.* Several limb-bones and a fragment of an upper molar of a rhinoceros are also known, but they are too imperfect for specific determination. The other known fossils belong to ruminants; the best preserved specimen being the greater portion of the cranium of an antelope, provisionally referred to the living Tibetan genus *Pantholops*, under the name of *P. hundesiensis;* this specimen cannot now be found, but is figured in Royle's "Illustrations of the Botany of the Himalaya Mountains." There is also a cranium said to belong to some genus of bovine animal; another belonging to a goat resembling the markhoor (*Capra falconeri*); and a palate, in the collection of the Geological Society, doubtfully referred to a sheep (*Ovis*).

Coming to the Siwaliks it will be convenient to chronicle the fauna of both the upper and lower divisions in the same paragraphs, as a considerable number of forms are common to the two; the upper division is certainly pliocene, but it is not improbable that the lower division, as exemplified in Sind, Kach, and the regions to the north and west, may be of upper miocene age.[2] Some fossils from certain parts of the Sub-Himalayan region may however have been obtained from the lower division; while some of the mammals from Perim Island have an old facies (*Dinotherium* and *Hyotherium*), although others (the ruminants) are of a later type.

Remains of Primates are of extremely rare occurrence, and all the known species are founded upon very small and imperfect fragments of the skull or upon individual teeth. In the *Simiidæ*, the type genus *Simia* is represented by an imperfect upper canine apparently belonging to a species closely allied to the existing orang of Borneo; while a broken palate indicates a species of chimpanzee (*Troglodytes siva-*

[1] In the previous edition of this memoir these strata were referred to the pleistocene, but the author is now inclined to revert to the older view of regarding them as high up in the pliocene.

[2] Prof. Duncan (Quart. Journ. Geol. Soc. Vol. XXXVII: p. 207) includes both divisions in the pliocene, but Dr. Blanford in his latest work on Sind (Mem. Geol. Surv. Ind. Vol. XX. p. 5) refers the lower division to the upper miocene.

lensis[1]) distinguished from the existing African *T. niger* by the narrower last premolar. In the family *Cercopithecidæ*, *Semnopithecus* is represented by *S. palæindicus* which is equal in size to the existing Indian *S. entellus*, but has a less deep mandibular ramus; *Macacus*, by the small *M. sivalensis*; and *Cynocephalus*, now characteristic of Africa, by two species, one of which (*C. subhimalayanus*) agrees in dimensions with *C. anubis*, while the other (*C. falconeri*) is considerably smaller. The genus *Cynocephalus* presisted in Southern India to the pleistocene.

In the Carnivora the family *Felidæ* comprises two species of *Machærodus*,—one (*M. palæindicus*) being as large as the tiger, and the other (*M. sivalensis*) about equal in size to the jaguar. In the structure of the skull both species present characters connecting them with the American forms, but two lower premolars were developed as in *M. aphanistus* of Pikermi. *Felis* is represented by the large *F. cristata*, which is about equal in size to the tiger, but has cranial characters allying it more closely with the lion and the jaguar; and also by *F. brachygnatha*, which may be generically identical with *Cynælurus*; as well as by two other unnamed forms, of which one is allied to *F. pardus*, and the other to *F. lynx*; and also by the small *F. subhimalayana* of dimensions nearly the same as those of the living *F. bengalensis*. *Ælurogale sivalensis* is named on the evidence of a mandibular ramus from the Punjab which appears generically identical with this genus of primitive cats originally described from the Quercy phosphorites, and shows the presence of three lower premolars. *Æluropsis* is a genus peculiar to the Siwaliks, founded upon a mandible from the Punjab, apparently connecting *Machærodus* with the *Hyænidæ*, and accordingly named *Æ. annectans*. In the *Hyænidæ* a peculiar mandible from the Punjab has received the name of *Lepthyæna sivalensis*, and apparently indicates an animal connected both with *Ictitherium*, *Hyæna*, and the primitive cats. *Hyæna* itself is represented by four named species, and an unnamed form which may be specifically distinct. Two of these species—*H. colvini* and *H. felina*—are closely allied to the South African *H. crocuta* (which it will be remembered occurs in the pleistocene of Madras); and it is probable that the first of the two Siwalik species is the ancestor of the latter. *H. sivalensis* is a primitive form allied to the Indian *H. striata* (of which it may be the ancestor), but distinguished by the presence of a second lower true molar; it is closely allied to *H. græca* of Pikermi (which has been generically separated as *Hyænictis*) but has one lower premolar less. The most remarkable of the Siwalik hyænas is, however, *H. macrostoma*, which in its elongated premolars connects the more typical species with the *Viverridæ* and canoids, and is closely allied to the Pikermi *H. chæretis*, which has been generically separated by some under the name of *Lycyæna*. In the *Viverridæ* two species of Siwalik *Viverra* are known, of which *V. bakeri* is of the size of *V. zibetha*, while *V. durandi* is larger than any existing species; both forms present certain characters connecting them with *Ictitherium*; and it is not improbable that *V. bakeri* may have been the ancestor of *V. karnuliensis* of the Madras pleistocene, from which form the living Indian species may in its turn have descended. In the *Ursidæ* (which are taken to include both the bears and the dogs) the dogs are represented by *Canis cautleyi* and *C. curvipalatus*; the former being closely allied to the wolf; while the latter shows indications of affinity with the African *Otocyon*. The

[1] Originally described under the name of *Palæopithecus*.

genus *Amphicyon*, distinguished from *Canis* by the presence of an additional upper true molar, is represented by *A. palæindicus*, which is allied to *A. intermedius* of the middle miocene of Styria. The bears are represented by the genera *Ursus* and *Hyænarctos:* of the former there is a skull, without teeth, from the Sub-Himalaya which has received the name of *U. theobaldi* and appears to have been the ancestor of the living Indian *U. labiatus*, whose remains, as we have seen, occur in the pleistocene of the Karnul Caves. Of *Hyænarctos* three species have been named; *H. sivalensis* has the upper molars with quadrangular crowns, and is known by a fine cranium, the half of a mandible, and some limb-bones, in the British Museum; *H. punjabiensis* is an allied form from the Punjab distinguished by the smaller size of the anterior lobe of the upper carnassial tooth; while *H. palæindicus*, known by a maxilla and mandible in the Indian Museum, is characterised by the triangular form of the crowns of the upper molars, which approach those of the European miocene genus *Dinocyon*, and not improbably by the absence of the third lower true molar. In the *Mustelidæ* the type genus *Mustela* is known by a small fragment of a mandible indicating a species of the size of *M. flavigula*. Two species of *Mellivora*, or ratel, have been described, of which the first (*M. punjabiensis*) is closely allied to the existing Indian *M. indica* and the African *M. capensis*, while the second (*M. sivalensis*) is distinguished by the different proportions of the premolars. *Mellivorodon palæindicus* is an allied form described upon the evidence of a mandibular ramus from the Punjab. Of the otters the small *Lutra palæindica* has been named from the evidence of a skull and lower jaw in the British Museum, apparently allied to *L. vulgaris;* a second species is indicated by a lower jaw from the Punjab. in the Indian Museum, which has been named *L. bathygnatha*, and indicates an animal allied to the African *L. lalandi;* while a very large form of otter named by Falconer *Enhydriodon sivalensis* has been included by the present writer in the type genus *Lutra*, with which it is connected by the large *L. campani*[1] of the middle miocene of Italy, which is evidently allied to the living Indian *L. leptonyx*. The last member of the Siwalik Carnivora belongs to the suborder Primigenia (Creodonta of Cope) and has been referred to the genus *Hyænodon*, with the specific name of *H. indicus;* this genus is indeed confined in Europe to the older tertiaries, but it appears that the South American upper tertiary form to which Bravard applied the name *Eutemnodus* is really identical.

Turning to the Ungulata we find the Proboscidean suborder very abundantly represented, species of all the known groups being present. The most specialized group is represented by *Elephas hysudricus*, of which the molars are of less complex structure than those of *E. indicus*. *E. planifrons* is remarkable for being one of the two species of true elephant in which premolars are known to have been developed. The stegodont group, peculiar to South-Eastern Asia, is represented by four species; of these the molars of *E. ganesa* and *E. insignis* appear to be indistinguishable from one another; the skull of the former, however, of which there is a magnificent specimen in the British Museum, is distinguished by its enormous tusks, and that of the latter, of which there are numerous specimens, by the pecu-

[1] This species was referred to *Enhydriodon* by Dr. Forsyth-Major, a reference which had escaped the writer's notice when describing the Siwalik form in the Palæontologia Indica.

liarly depressed form of the fronto-parietal region. Molars of *E. insignis* have been obtained from strata of probably pliocene age in Japan, and not improbably also from Java; as well as from caves in China.[1] The molars of the third species, *E. bombifrons*, are less complex than those of the preceding; and its skull has very prominent frontals. Of the fourth species, *E. clifti*, the skull is unknown, but the molars are still simpler, the intermediate ones frequently bearing only six ridges each; remains of this species have also been obtained from Burma, Japan, and China, a tooth from the latter country having been named *Stegodon sinensis;* premolars were developed in a specimen referred to this species. Eight species of mastodons are known, five belonging to the tetra-, and three to the trilophodont division of the genus. Of the former, *Mastodon latidens* approaches nearest to the stegodont group of *Elephas*, and since its molars have open valleys, and the intermediate ones occasionally carry five ridges, it affords such a complete transition between *E. clifti* and the other mastodons, as to show that the generic division between the elephants and mastodons is merely nominal. The skull of *M. latidens* is unknown; and its remains have been obtained from the Irawadi valley, the Sub-Himalaya, Sind, Perim Island, and Borneo. Closely allied to this species is one from Perim Island to which the name *M. cautleyi* has been provisionally applied, a form connecting *M. latidens* with the European *M. longirostris*. *M. punjabiensis* is a species less closely allied, and presenting some approximation in dental characters to *M. perimensis* of Perim Island, in which the columns of the molars have a tendency to an alternate arrangement, and a considerable quantity of cement is present in their valleys. The fifth tetralophodont species, *M. sivalensis*, has the molars with a distinctly alternate arrangement of the ridges, and occasionally presents a tendency to a pentalophodont formula; there is a fine skull in the British Museum, and its remains have been obtained only from the Sub-Himalaya. The skulls of the two peculiar trilophodont species are unknown, and all their remains are from the Punjab, Sind, and Perim Island. In the first, *M. falconeri*, the valleys of the molars are open, and the symphysis of the lower jaw is short, and sometimes provided with small cylindrical tusks; but in the second, *M. pandionis*,[2] the valleys are obstructed by outlying columns, and the symphysis of the lower jaw is produced into a long trough-like process, which may or may not be furnished with large, compressed tusks. The third species, of which the remains have been found only in the regions across the north-west frontier, is a variety of *Mastodon angustidens* of the middle miocene of Europe. Two species of *Dinotherium* are known, of which *D. indicum*,[3] rivals in size the European *D. giganteum*; there are several specimens of the teeth and jaws in the Indian Museum, and also in the collection of the Bombay Branch of the Royal Asiatic Society; the British Museum possesses also the cast of a cervical vertebra, part of the mandible, and some molars; remains of this species have been obtained from the Sub-Himalaya, Punjab, Perim Island, Kach, and Sind. The second species, *D. sindiense*, is only known by two specimens of a part of the man-

[1] Described under the name of *Stegodon orientalis*.

[2] The type specimens of this species were said to have been obtained from the Deccan, but appear really to have come from Sind.

[3] The form known as *D. pentapotamiæ* is now provisionally regarded as merely a small variety.

dible, one from Sind and the other (lacking the crowns of the molars) from the Punjab; both specimens are in the Indian Museum. The mandible in this species is subcylindrical in cross-section, and thereby approaches that of the mastodons.

In the Perissodactylate suborder the symphysis of a mandible from Burma has been referred to *Tapirus*, but the determination must be considered uncertain. The horses are represented by the genera *Equus* and *Hipparion*; of the former there are two species, *viz.*, *E. sivalensis*, apparently closely allied in dental characters to the pliocene European *E. stenonis*, but with a cranium resembling that of *E. hemionus*; and *E. namadicus*, in which the cranium and molars resemble those of *E. caballus*. *E. namadicus* apparently occurs only in the topmost Siwaliks. Of *Hipparion* there are apparently at least three species; *viz.*, *H. antilopinum* agreeing in size with *H. gracile*, but with only one functional digit to each foot; a second form, to which the name *H. punjabiense* has been provisionally assigned, of nearly the same dimensions, but apparently having three complete digits; and a larger species with the same number of digits known as *H. theobaldi*. A fragment of an upper jaw from Perim Island could not be satisfactorily identified with either of these three forms, and if distinct the name of *H. feddeni* has been suggested for it. The genus *Rhinoceros*, if that term be employed in its widest sense, was abundantly represented in the Siwaliks. The sole member of the atelodine group is *R. platyrhinus*, which appears closely allied to, and is perhaps the ancestor of, both the living African *R. simus* and the pleistocene *R. antiquitatis* of Northern Europe and Asia. In the rhinocerotic group *R. sivalensis* was apparently very closely allied to the living *R. sondaicus*, which it resembles in the form of its molars and the mandible. Skulls and teeth of this species are contained both in the British and Indian Museums, and its remains have been obtained from the Sub-Himalaya and Sind. The second species, *R. palæindicus*, was also unicorn, and the mandible has a pair of incisors; the upper molars are intermediate in structure between those of the living *R. sondaicus* and *R. unicornis*, and it is not improbable that the fossil species was the ancestor of the latter. The hornless rhinoceroses are represented by the gigantic *R. perimensis*, of which there is a fine cranium and numerous teeth and jaws from the Punjab in the Indian Museum, and a magnificent palate and some specimens of the mandible from Perim Island in the collection of the Bombay Branch of the Royal Asiatic Society; the British Museum also possesses a few specimens of teeth and jaws from Perim Island. *R. blanfordi* from the Bugti hills is a second hornless species closely allied to *R. incisivus* of the lower pliocene of Europe. The genus *Chalicotherium* is represented by *C. sivalense*,—a species presenting a peculiarly aborted dentition, and hence referred by some to a distinct genus, under the name of *Nestoritherium*. This species is of rare occurrence, but is known by an associated cranium and mandible, in the Museum of Mareschal College, Aberdeen, by the upper molars of each maxilla, and a mandible in the British Museum, and by a few lower molars in the Indian Museum. The latter specimens are from Sind, and the others from the Sub-Himalaya. Another species has been described from the pliocene of China, under the name of *C. sinense*.

The suborder Artiodactyla includes a very large number of both genera and species. Of the true oxen (*Bos*), three species have been named, *viz.*, *B. acutifrons*, remarkable for its enormous horns and angulated frontals; *B. planifrons*, with

shorter horns and flattened frontals, and closely allied to the European *B. taurus;* and *B. platyrhinus*, only known by the lower half of a cranium, of which the generic affinities are doubtful. The latter specimen, and the cramia of each of the preceding species, are in the Indian Museum, and came from the Sub-Himalaya. Species of *Bos* or allied genera are indicated from Perim Island by molars in the Museum of Science and Art, Dublin. One cranium from the Sub-Himalaya, in the Indian Museum, belongs to a species of *Bison*, which has been named *B. sivalensis;* it is the earliest form of the genus, and seems to have been allied to *B. europæus.* The genus *Bubalus* is represented by several species; the first of which, *B. platyceros*, is known by one cranium in the British, and another in the Indian Museum, both being from the Sub-Himalaya; the horns were stout and concave superiorly. The second species is either closely allied to, or identical with the living *B. buffelus*, which occurs in the pleistocene, if, indeed, the topmost beds of the Siwaliks in which the present form is found do not belong to the same period. There are three other species[1] of this genus more or less closely allied to the anoa (*B. depressicornis*) of Celebes; the first of which is named *B. occipitalis*, and varies considerably in the form of its horn-cores, which are sometimes nearly straight, and triangular in section, and at others curved, and pyriform in section, another variety being hornless. There are fine series of the crania of this species, both in the British and the Indian Museum, all from the Sub-Himalaya. The second species, *B. antilopinus*, is also known by several crania from the same districts. The third, *B. acuticornis*, is a long-horned form, and is represented by numerous skulls, from the Sub-Himalaya, in the British and Indian Museum. *Leptobos falconeri* is another form of bovine (in some cases hornless), of which there are several crania in the British Museum.

A remarkable hornless skull, of comparatively large size, from the Sub-Himalaya, in the collection of the British Museum, has been described under the name of *Bucapra daviesi;* this specimen comes nearest to the skulls of the goats, but has molars of a bovine type, which if found separately would certainly have been referred to some form of oxen. There is evidence of three species of true goats, the first of which, *Capra sivalensis*, is known by two crania in the British Museum from the Sub-Himalaya, and is considered to be allied to the so-called ibex of the Nilgherries (*Capra jemlaica*). The second species, *C. perimensis*, is known by a portion of a cranium in the Indian Museum, from Perim Island, and was probably allied to the living markhoor (*C. falconeri*) of the Himalaya, though the horn-cores do not show a spiral twist. The third form is unnamed, since its horn-cores, of which the Indian Museum possesses numerous specimens from the Punjab, are so like those of the markhoor, that it is difficult to point out characters of specific distinction with the materials available; it is possible that these horns may belong to older individuals of *C. perimensis.* It has been stated that a cranium from the Sub-Himalaya, which is not now forthcoming, is specifically identical with the living Himalayan ibex (*C. sibirica*), but this determination requires confirmation, although it is highly likely that the specimen may have belonged to an allied species. Another cranium, also lost, has been referred to the genus *Ovis.* Coming to the antelopes,

[1] Originally described under the names of *Hemibos, Amphibos, Probubalus,* and *Peribos;* the synonymy, which is much involved, will be found in part ii of the writer's 'Catalogue of Fossil Mammalia in the British Museum.'

an imperfect cranium from Perim Island belongs to the existing African strepsicerine section and has been named *Strepsiceros* (?) *falconeri*[1]; while maxillæ from the Punjab have been provisionally referred to *Oreas* under the name of *O.* (?) *latidens*. The existing Indian genus *Boselaphus* is indicated by numerous jaws, teeth, and limb-bones, but none of these specimens afford characters sufficient to determine whether the Siwalik nilghai is distinct from the Narbada *B. namadicus*. The African genus *Hippotragus* is represented by *H. sivalensis*, of which the British Museum has a fairly perfect cranium; while the more widely spread *Gazella* is known by *G. porrecticornis*, and not improbably by a smaller unnamed species from the Punjab. Two species of antelope, in which the females were unprovided with horns as in the existing African genus *Cobus*, have been provisionally referred to that genus under the names of *C.* (?) *palæindicus* and *C.* (?) *patulicornis*, and in any case indicate closely allied forms. A small antelope closely resembling in general characters the existing Indian *Tetraceros quadricornis* has been named *T. daviesi*, and apparently differs from the former chiefly in the characters of the upper premolars; while it has been suggested that a fragment of the maxilla of a still smaller antelope may possibly belong to the African genus *Cephalopus*. *Alcelaphus palæindicus* is a large antelope presenting cranial characters intermediate between those of the hartebeaste and the blessbock.

The family *Giraffidæ* is taken to include *Sivatherium* and its allies, and is thus strongly represented in the Siwaliks. There has been considerable discussion as to the serial position of the following forms; *Helladotherium*, with the giraffe, being classed by some with the deer, while *Sivatherium* and the two succeeding genera are grouped with the antelopes. The resemblance of the teeth and bones of all these animals is, however, so close that it seems preferable to class them all together in one large family, connecting the deer with the antelopes. The first genus is the well-known *Sivatherium*, represented by the one species *S. giganteum*, in which the skull was furnished with two pairs of horns. Remains of this species have been obtained only from the Sub-Himalaya eastward of the Punjab, and of these the British Museum possesses a magnificent series. The second genus *Bramatherium* is known by *B. perimense*, of which the cranium, teeth, mandible, and some of the limb-bones are known; this species carried a pair of horns above the occiput, and a large common horn-base on the frontals. Its remains have been obtained from Perim Island, and the one known cranium is in the Museum of the Royal College of Surgeons; upper molars are in the British Museum, two fragments of the mandible in the Indian Museum, and another, with the last true molar, in the Museum of Science and Art, Dublin. Of *Hydaspitherium*, there are two species, of which *H. megacephalum* is known by a cranium and a large series of teeth and bones; all from the Punjab, and preserved in the Indian Museum; it carried a massive common horn-base above the occiput from which the horns took their origin. The second species, *H. grande*, was larger and is only known by the upper molars and the mandible; all of which are from the Punjab, and are now in the Indian Museum. It is probable that a cervical vertebra from Beluchistan, in the collection of the Geological Society, belongs to one of the above forms. A species of *Hel-*

[1] Teeth formerly provisionally referred to *Palæcryx* apparently belong either to this or an allied species.

ladotherium, apparently indistinguishable from *H. duvernoyi* of Europe and Persia, is represented by a single cranium in the British Museum. The last of the four genera peculiar to the Siwaliks is *Vishnutherium*, which is known by a part of the mandible from Burma, and probably by two upper molars and some bones from the Punjab, all of which are in the Indian Museum. It seems to come the nearest of the four to the giraffe, and has been named *V. iravaticum*. The one species of *Giraffa* (*G. sivalensis*) appears closely allied to the existing giraffe, and also to the extinct *G. attica* of Greece and Persia; it has been found in the Siwalik hills, the Punjab, and Perim Island.

In the *Cervidæ* three specific names have been applied to forms referred to *Cervus*, but in one instance the generic reference may be incorrect; *C. sivalensis* has been assigned to the rucervine group characteristic of South-Eastern Asia, the antlers probably belonging to it presenting characters intermediate between those of *C. duvaucelli* and *C. eldi*. One upper molar from the Punjab has been provisionally referred to *Moschus;* while another molar from the same region indicates a species of *Palæomeryx* (*P. sivalensis*) equal in size to the large *P. bojani* of the middle miocene of Europe. There are two species of *Camelidæ*, both belonging to the type genus, and respectively named *Camelus sivalensis* and *C. antiquus;* in the lower true molars of both species there is a vertical ridge now found only in the American *Auchenia*, and their cervical vertebræ are intermediate in structure between those of the latter and those of the existing species of *Camelus*. In the *Tragulidæ* a species of *Tragulus* has been named *T. sivalensis* on the evidence of an upper molar from the Punjab; and *Dorcatherium* (which is probably identical with the existing African *Hyomoschus*) is represented by the two species *D. majus* and *D. minus*. *Chœromeryx silistrensis* is a peculiar tetracuspidate brachydont form provisionally referred to the *Dichodontidæ*, which has been obtained both from Sylhet and Sind.[1] A single upper molar from Sind, in the Indian Museum, apparently belongs to the North American family *Oreodontidæ*, and has been provisionally referred to the genus *Agriochœrus;* it seems very close to *A. latifrons*. The name *Hemimeryx blanfordi* has been applied to a large selenodont upper molar from Sind, which appears closely allied to one species of *Merycopotamus*, and may eventually prove to be generically identical. Of *Merycopotamus* itself (which on account of the presence of only four cusps to the upper true molars is made the type of a distinct family, although included by some writers in the *Anthracotheriidæ*) there are three species, of which the typical *M. sivalensis* is the largest. The smaller *M. nanus* is readily distinguished by its relatively shorter jaws; while the still smaller *M. pusillus* (known only by a single upper molar from Kushalgarh in the Punjab) presents a difference in the structure of the upper molars, and apparently thereby approximates to the *Dichodontidæ*.

Of the selenodont pig-like animals, with five columns on the upper molars, forming the family *Anthracotheriidæ*, we have two named species of *Anthracotherium*, and two of *Hyopotamus*. Of the former, one species (*A. silistrense*) is of small size, and is known by three upper molars, and parts of the mandible; these specimens have been obtained from near Sylhet, the Punjab, and Sind, and most of them are in the Indian Museum. The second species, *A. hyopotamoides*, is of very large size, and

[1] The Sind form was originally separated under the name of *Sivameryx sindiensis*.

is known by wo upper molars in the Indian Museum, from the Bugti hills, to the north of Sind; some imperfect specimens of the mandible may also belong to this species. In addition to these named forms there are also two fragments of mandibular rami in the British Museum from the Siwalik hills, which apparently indicate the occurrence of two other species intermediate in size between *A. silistrense* and *A. hyopotamoides*. Of *Hyopotamus*, a small species, *H. palæindicus*, is known by several teeth and one lower jaw, from Sind, in the Indian Museum; the molars of this species have very low crowns and differ somewhat in structure from those of all the European forms. The second species, *H. giganteus*, is known by two upper molars, and by some specimens of the mandible from the Bugti hills, now in the Indian Museum; the upper tooth much resembles that of *Anthracotherium hyopotamoides*, and with that species forms a complete transition between *Anthracotherium* and *Hyopotamus*. A peculiar form of pig-like animal from the Sub-Himalaya known as *Tetraconodon magnus* is apparently allied to *Elotherium*, but distinguished by the presence of a hind talon to the last lower molar, and by the enormous size of the premolars. The former character approximates this genus to the *Suidæ*, and tends to indicate the advisibility of retaining the family *Chæropotamidæ* for *Chæropotamus* and *Elotherium*, rather than of including these genera in the *Anthracotheriidæ*. In the *Suidæ*, *Hyotherium* is represented by *H. sindiense* of the lower Siwaliks of Sind, and *H. perimense*[1] of Perim Island; the former being apparently allied to *H. sæmmeringi* of the middle miocene of Styria and other parts of Europe, while the latter is distinguished by the great relative width of the lower true molars. *Hippohyus* is a peculiar Siwalik form apparently allied to *Hyotherium*, in which the columns of the cheek-teeth have attained an excessive complexity of structure; it is represented by the typical *H. sivalensis*, and not improbably by a second unnamed species. *Sanitherium schlagintweiti* is a smaller form apparently allied to the present group, and known only by a few fagments of the mandible obtained from Kushalgarh. *Sus* is represented by five named species; among which *S. titan* is the largest pig known in the world; its molars are of a simple structure, the talon of the last one being of small size. *S. giganteus* is a somewhat smaller species also having simple molars, in which the cranium approximates to that of *S. vittatus*; the mandible provisionally referred to this species is characterized by the unusual width of the premolars. *S. falconeri* is a species usually somewhat larger than the existing *S. cristatus*, and characterised by the extreme complexity of the true molars, especially the last, in which respect this species, in common wtth *S. phacochæroides* of the pliocene of Algeria, makes a decided approach towards *Phacochærus*; and it is not improbable, as mentioned above, that *S. cristatus* is descended from it: the elongated facial portion of the cranium recalls that of *S. barbatus* of Borneo. *S. hysudricus* is a small species with simple molars, very closely allied to *S. palæochærus* of the European lower pliocene; while *S. punjabiensis* is of still smaller dimensions, and was not improbably the ancestor of the pigmy *S. salvanius* of the Nipal terai. Some unnamed specimens may indicate a sixth species of the genus. The genus *Listriodon*, the type of a separate family, is represented by *L. pentapotamiæ* and *L. theobaldi*, the former being known by several molars, and the latter only by one molar of small size. All these teeth were obtained from the

1. Quart. Journ. Geol. Soc. Vol. XLIII. p. 19 (1887).

Punjab, and are in the Indian Museum. Finally, in the *Hippopotamidæ* there are two species of *Hippopotamus*, both of which were furnished with three pairs of incisors; *H. sivalensis* was of comparatively large size, while the Burmese *H. iravaticus* was considerably smaller and has a relatively longer mandibular symphysis.

The remaining orders of the Mammalia are only represented by a few species of rodents, and by one edentate. Of the former, a species of *Nesokia*, apparently allied to the existing Indian *N. hardwickei*, is indicated by a mandibular ramus from the Sub-Himalaya. A species of bambu-rat (*Rhizomys sivalensis*) has been determined on the evidence of specimens of the mandible. A porcupine (*Hystrix sivalensis*) is known by a part of a young cranium and the mandible, the former, which is from the Siwalik Hills, being in the British and the latter, which is from the Punjab, in the Indan Museum; while a species of *Lepus* is indicated by a small fragment of a mandible in the British Museum. The Edentata are known only by one phalangeal bone from Sind which was originally named *Manis sindiensis*, but subsequently referred to *Macrotherium*. This bone apparently indicates a species intermediate between typical species of the latter genus and *Manis*, and it had been suggested that *Manis gigantea* may have descended from this form.

Miocene.—The only determined undoubted miocene mammal is a small rhinoceros from the Gaj beds of Sind, which has been regarded as a variety of *R. sivalensis*, and named *var. gajensis*; it is, however, quite probable that it may be specifically distinct.

Eocene.—No traces of mammals have yet been detected below the eocene, and in that formation only some very fragmentary bones have been obtained from the Punjab. The determinable bones consist of the distal portions of the femur and the metatarsus of a perissodactyle animal, allied to, if not identical with, *Palæotherium*; and the astragalus of an artiodactyle. The latter was obtained above the nummulitic clays of Fatehjang, and apparently belonged to an animal, in which the navicular and cuboid elements of the tarsus were united. These specimens are in the Indian Museum.

CLASS II.—AVES.

Pleistocene.—The Karnul caves have yielded a small number of bird-remains all of which have been referred to existing Indian species. These comprise *Neophron percnopterus*; a smaller accipitrine bird which may be a *Milvus* or a *Circus*; the Ceylon fish-owl (*Ketupa ceylonensis*); an eagle-owl, *Bubo coromandus*; two species of francolin, *Francolinus pictus*, and *F. pondicerianus*; a crane which is very probably *Grus communis*; and the black-headed ibis (*Ibis melanocephala*).

Pliocene.—Remains of birds have hitherto been found only in the upper Sub-Himalayan Siwaliks, and their numbers are still very small. Some of these remains are in the British and others in the Indian Museum. Among the Carinatæ, a tarso-metatarsus has been considered to belong to a cormorant, and is provisionally referred to the genus *Phalacrocorax*. A species of pelican (*Pelecanus cautleyi*), somewhat smaller than the living Indian *P. mitratus*, is indicated by a fragment of the ulna; while another fragment of the homologous bone has been referred to a second species, under the name of *P. sivalensis*, but there is some doubt whether the generic determination is correct. A species of adjutant-stork, which appears to have had

considerable variations in size, has been named *Leptoptilus falconeri*; while a cervical vertebra from the Punjab indicates another genus of the same group. Another cervical vertebra from the same district has been provisionally referred to *Mergus*. The Ratitæ appear to have been represented by two species, one of which was a true ostrich (*Struthio asiaticus*[1]), and is known by several bones of the leg and foot, and some cervical vertebræ; while the other was a three-toed form of which the genus has not been determined.

CLASS III.—REPTILIA.

I.—TERTIARY.

Pleistocene.—The reptilian remains from the Karnul caves comprise a tooth of a species of *Crocodilus*; numerous bones of the existing Madras monitor (*Varanus dracæna*); and, in the *Ophidia*, vertebræ of *Python molurus*, of the cobra (*Naia tripudians*), and of a large snake provisionally identified with *Ptyas mucosus*. Some other small ophidian, as well as chelonian, remains have not been even generically identified.

The reptiles of the older pleistocene are still very imperfectly known, but it is probable that they all belong to living Indian species. From both the Jamna and Narbada beds specifically indeterminable remains of crocodiles have been obtained. A complete specimen of the carapace of *Pangshura flaviventris*[2] from the Narbada is in the Indian Museum, and serves to connect the living with the Siwalik form, and also shows that the range of the species once extended over the greater part of India; a less perfect specimen in the same Museum may also belong to this species. A portion of the plastron of a *Batagur* from the Narbada valley has been provisionally referred to *B. dhongoka*, now found in that river. A fragment of the carapace of a *Trionyx*, from the same deposits, probably belonged to *T. gangeticus*, and a cranium in the British Museum gives more certain evidence of the occurrence of that species.

Pliocene and (?) upper miocene.—The Chelonia of the Siwaliks although still imperfectly known, are represented by a considerable number of forms. In the *Testudinidæ* the gigantic *Colossochelys atlas* is the largest of all known forms; it is distinguished from *Testudo* by the non-union of the pygal plates[3] of the carapace, and by the production of the plastron anteriorly into a pair of cornua, supported on the ventral aspect by a strong triangular keel on which the gular plates are borne; the length of the restored carapace in a straight line is 8 feet 4 inches. Four other forms of gigantic land-tortoises are indicated by remains which are not sufficiently perfect to admit of generic determination. The first of these species is about one-half larger than the living *Testudo elephantina* of Aldabra, and has an epiplastron intermediate in structure between that of *Colossochelys atlas* and that of the existing Indian *Manuria emys*. The second, which may be identical with the form to which the name *Cautleya annuliger* has been applied, is about one-fourth larger than *T. elephan-*

[1] A limb-bone of this species, and a specimen which is apparently not avian at all, were made the types of the genus *Megaloscelornis*. Other bones were referred to *Dromæus* but these also turn out not to be avian.

[2] Originally described as *P. tectum*.

[3] The term plate is applied to the horny epidermal covering, and scute to the subjacent bony layer.

tina. The third is of nearly equal dimensions, but has a very different epiplastron; while the fourth is considerably smaller, and appears more nearly allied to the existing land-tortoises of India and Burma. In the *Emydidæ*, *Clemmys* is represented by several forms, six of which have received distinct specific names. Of these *C. sivalensis* is allied to the existing *C. crassicollis* of India and the neighbouring regions, but has no nuchal plate; *C. hydaspica* is an allied form in which the nuchal plate is present; while a third member of the same group is found in *C. theobaldi* which has an unusually depressed carapace, with a first vertebral plate of very remarkable shape. *C. punjabiensis* is a form with a bell-shaped first vertebral plate, in which respect it resembles certain North American species of the genus; its hinder vetebrals have not the 'mushroom-shape,' characteristic of the three preceding species. A fifth unnamed species comes so close to the existing Indian *C. trijuga*, that it may be pretty safely regarded as the ancestor of that species, if indeed it be not identical. From Perim Island a shell with quadrangular vertebral plates has received the name of *C. watsoni* [1]; while *C. palæindica* of the Siwalik hills appears closely allied to the tricarinate *C. hamiltoni* of India, of which it may have been the ancestor. An unnamed form from Perim Island may perhaps indicate an eighth species of the genus. The characteristic Indian genus *Pangshura* is represented by a form provisionally identified with the existing *P. flaviventris*, which, as we have seen, also occurs in the pleistocene; and by an unnamed species apparently more nearly allied to *P. tectum* and *P. tentoria*. Of *Batagur*, a genus confined to the Oriental region, there are four named species. Of these *B. falconeri* is regarded as the ancestor of the Indian *B. thurgi*; *B. bakeri* is equally closely allied to the existing *B. kachuga*; *B. durandi* shows a strong resemblance to *B. dhongoka*; while *B. cautleyi* presents affinity to *B. affinis* and *B. pictus*, respectively of the Malayan peninsula and Borneo. A generically undetermined nuchal scute from the Punjab may belong to a member of the genus *Geoemyda*. In the *Trionychidæ*, *Emyda* is represented by the existing Indian *E. vittata*, and also by three extinct species respectively named *E. lineata*, *E. sivalensis*, and *E. palæindica*. The three latter differ from existing species in the structure of the nuchal scute, and the last two are of comparatively large size. *Trionyx* was probably represented by several species, but none of the specimens yet obtained have afforded satisfactory characters for specific diagnosis. Lastly, the peculiar Indian genus *Chitra* is represented by the existing *C. indica*, which is the only known species.

In the Crocodilia, *Crocodilus sivalensis* is very closely allied to the existing Indian *C. palustris*; while *C. palæindicus* of Perim Island is another member of the same group distinguished by its convex facial profile. The gharials are represented by the existing *Garialis gangeticus*; and by an allied form known as *G. hysudricus*, which is distinguished by the form of the rostrum, and probably also by that of the cranium proper. *G. curvirostris* from the lower Siwaliks of Sind is a very distinct form characterised by the non-eversion of the anterior border of the orbit, and probably allied to certain upper cretaceous gharials of North America which have been generically separated under the name of *Holops*. *G. leptodus* is known only by the rostrum, which presents certain characters approximating it to *Tomi-*

[1] Quart. Journ. Geol. Soc. Vol. XLII. p. 540 (1886).

stoma. In *G. pachyrhynchus* of the lower Siwaliks of Sind we have a gigantic species provisionally referred to the type genus presenting certain marked peculiarities in the relations of the anterior teeth and their pits. Finally another gigantic species from the upper Siwaliks has been made the type of the genus *Rhamphosuchus*, with the specific affix of *crassidens*, and indicates a gharialoid presenting features in the relations of the upper and lower dentition now found only in the short-jawed alligatoroid members of the order.

The Lacertilia are only known by the gigantic *Varanus sivalensis*, which is estimated to have attained a length of eleven feet. The group appears to be an old one, as it is represented by the closely allied, if not generically identical, *Palæovaranus* of the Quercy phosphorites.

The only remains of *Ophidia* hitherto obtained from the Siwaliks are vertebræ of the genus *Python* from the Punjab and Sind. Some of these specimens have been provisionally identified with the existing Indian *P. molurus*, while others may indicate a distinct species. A python from the Quercy phosphorites, originally named *Python cadurcensis*, but regarded by some as generically distinct and therefore named *Palæopython*, carries back the origin of these huge serpents to a remote epoch.

Eocene.—The only specifically determined eocene reptile may be referred to the genus *Platemys*, under the name *P. leithi*.[1] The specimen on which this determination rests is a carapace from the inter-trappeans of Bombay. The genus *Platemys* belongs to the *Chelydidæ*, and, although occurring in the Purbeck and lower eocene of England, is now confined to South America; the section or suborder (*Pleurodira*) of which that family is a member being characteristic at the present day of the southern hemisphere. From the nummulitics of the Punjab numerous fragmentary remains of crocodilians have been obtained, but are in too imperfect condition for determination. Remains of large chelonians have recently been obtained from below the coal-beds at Nila in the Salt-range, which are apparently transitional between the eocene and cretaceous. These specimens apparently belong to two genera; and for one which presents the peculiar feature of having the carapace covered with horny plates, while the plastron is pitted as in the *Trionychidæ*, the name of *Hemichelys warthi* is proposed; like *Platemys*, it belongs to the *Pleurodira*.

II. Mesozoic and Palæozoic.

Cretaceous.—From the Arialur group (upper cretaceous) of the Trichinopoli series, and probably from the Lameta group (higher cretaceous), there have been obtained a few teeth of species of *Megalosaurus*, a genus whose range in England extends from the jurassic to the wealden, but is also found in the Maestricht beds of the Continent; the one tooth of the Indian form now forthcoming is in the Indian Museum. From the Lameta group there have also been obtained the remains of another genus of gigantic dinosaur, to which the name *Titanosaurus* has been assigned, which was represented by two species—*T. indicus* and *T. blanfordi*; the

[1] Referred by Gray ('Ann. Mag. Nat. Hist.' ser. 4, Vol. VIII., p. 339) to *Hydraspis*, which is now usually included in *Platemys*. The species was originally described by Carter as a *Testudo*.

former characterised by the centra of the caudal vertebræ being compressed, while in the latter they are sub-cylindrical. Numerous vertebræ, chiefly caudal, and a huge femur, nearly 4 feet in length, are preserved in the Indian Museum, and there is a cast of one of the former, belonging to *T. indicus*, in the British Museum. These forms, which have hitherto been regarded as allied to *Ceteosaurus* of the European wealden, but are referred to a separate family, appear much more closely related with *Ornithopsis* of the wealden, since a caudal vertebra from the Isle of Wight preserved in the British Museum, agrees very closely with the vertebræ of *T. blanfordi*, and agrees in relative size with *Ornithopsis*, of which the caudal vertebræ have been hitherto unknown. It may eventually prove that *T. blanfordi* is generically distinct from *T. indicus*. A few bones in the Indian Museum indicate a smaller undetermined reptile from the Lametas. The Chelonia are known in the cretaceous by some broken plates, in the collection of the Indian Museum, obtained from the Lametas, from the infra-trappeans of Rajamahendri (Rajamundry), and from the upper cretaceous of Sind. The Crocodilia are represented by one amphicœlian species, apparently allied to *Suchosaurus* of the English wealden, of which some vertebræ have been obtained from the upper cretaceous of Sind, and are now in the Indian Museum. A large species of *Ichthyosaurus* named *I. indicus* is known solely by a few vertebræ obtained from the Utatur group (middle cretaceous) of the Trichinopoli series, and now in the Indian Museum; the range of the genus in Europe is from the lias to the chalk.

Gondwana system.—The exact identification of the different members of the great freshwater Gondwana system of Peninsular India with European horizons must be regarded as still unsettled, although it is probable that the fossiliferous beds range from the jura to the permian.[1] From the Chari group of the jura of Kach there has been obtained a single vertebra, with an amphicœlian centrum, of which the affinities have not yet been determined, but which may be crocodilian[2]; and from the Umia group of the same, a fragment of the mandible of a *Plesiosaurus*, described as *P. indicus*; the affinities of the latter form cannot be fully determined from the specimen.

The Maleri group, whose fauna agrees with that of the upper trias of Europe, has yielded the primitive crocodilian *Parasuchus hislopi*, which is apparently allied to *Stagonolepis* of the Elgin sandstone, and is the type of the suborder Parasuchia; *Hyperodapedon huxleyi*, differing from the triassic European *H. gordoni* by the arrangement of the palato-maxillary teeth, and apparently by the presence of lateral teeth on the mandible; and a dinosaur apparently allied to the European triassic genus *Thecodontosaurus*. The Tiki group in South Rewah, which is provisionally

[1] In dealing with the vertebrates of certain Gondwana groups, I have shown that the evidence taken alone would indicate the following homotaxy of certain groups, *viz.*:—

Low. Jura.:—Kota. } (Jabalpur and Rajmahal.)
Up. Trias.:—Maleri. }
Low. Trias.:—Panchet.
Up. Permian:—Bijori and Mangli (Upp. Damuda).

This would indicate that the Barakars (Low. Damuda) correspond either with the lower permian or the upper carboniferous, and the Talchirs either with the upper or lower carboniferous. See Appendix, and 'Records', Vol. XIX, pp. 133-34 (1886).

[2] It has been suggested that this form may be *Parasuchus*; but the horizon renders this improbable.

correlated with the Maleri horizon has yielded the same rhynchocephalian and dinosaurian remains, but the crocodilian of the latter group is replaced by the European genus *Belodon*, so characteristic of the upper trias (keuper) of Germany. The oldest reptiles hitherto found in India occur near Raniganj in lower Bengal, in the Panchet group of the Gondwanas, of which the vertebrate fauna has a lower triassic facies. The remains of a species of *Dicynodon*, belonging to the *Ptychognathine* group, are of comparatively common occurrence in the coarse Panchet sandstone, and have been described as *D. orientalis.* Other remains seem to indicate a second and larger species of the genus. The suborder[1] of reptiles to which *Dicynodon* belongs is characteristic of the reputed trias of India, Russia, and Africa, and attained its fullest development in the latter country. The remains of the Indian forms all occur over a very small area in one thin seam of the Panchets. The dinosaur has been named *Epicampodon*[2] *indicus*, and is the sole representative of the genus; it is known merely by two minute, compressed, and trenchant teeth, with serrated edges like those of *Megalosaurus*, and implanted in distinct sockets. The above specimens are in the Indian Museum.

CLASS IV.—AMPHIBIA.

I.—TERTIARY AND POST-TERTIARY.

Pleistocene.—Remains of a large *Bufo*, probably identical with the existing Indian *B. melanostictus*, have been obtained from the Karnul caves in Madras.

Eocene.—In the eocene of Bombay there occur numerous remains of a small frog, belonging to the genus *Oxyglossus*, now living in China, Siam, and possibly India; the fossil species is extinct, and is known as *O. pusillus:* remains of a larger, but undetermined, frog are also indicated.

II.—MESOZOIC AND PALÆOZOIC.

Gondwana system.—The Denwa group of the Satpura district, which is probably not far removed in time from the Maleri horizon, has yielded the right supratemporal bone of a large species of *Mastodonsaurus* closely allied to *M. giganteus* of the upper and middle trias (keuper and muschelkalk) of Europe. Remains of another large labyrinthodont, apparently allied to the upper triassic (keuper) *Metopias* and *Capitosaurus*, have been obtained from the Maleri and Tiki (South Rewah) groups; while the former group has also yielded fragments of a *Pachygonia* which may be specifically identical with the Panchet form.

From the Panchet group three genera of slender-jawed labyrinthodonts allied to those of the European lower trias are known. The first of these, *Pachygonia*, has only the one species *P. incurvata*, and is known by the greater part of the mandible, and a fragment of the cranium. The marking of the former is like that of *Mastodonsaurus*. The second genus, *Gonioglyptus*, has two species, the smaller known as *G. longirostris* and the larger as *G. huxleyi*; it is considered to be closely allied to *Trematosaurus* of the bunter-sandstone of Germany. The third genus is

[1] The ordinal term Anomodontia is here used in a wide sense to embrace the Dicynodontia, Rhynchocephalia, Theriodontia, &c., which are ranked as suborders.

[2] Originally described as *Ankistrodon*—a name preoccupied by a genus of Pisces (*Ancistrodon*).

known only by a single fragment of a mandible, to which the name *Glyptognathus fragilis* has been applied. These three genera are peculiar to India, and all their remains are exhibited in the Indian Museum; the two former belonging to the section Euglypta. From the Mangli beds another peculiar genus of labyrinthodont has been obtained, and is represented by a single skull in the collection of the Geological Society, to which the name *Brachyops laticeps* has been applied. This genus is allied to *Rhinosaurus* from the jurassic of Europe, to *Micropholis* of the Karoo system of Africa, and to *Bothriceps* of the reputed trias of Australia, and with them constitutes the section Brachyopina. The oldest Indian labyrinthodont at present known is represented by the greater portion of a skeleton obtained from the Bijori group, and has been referred to the *Archegosauridæ* under the name of *Gondwanosaurus bijoriensis*; it presents the peculiar type of vertebral structure to which Professor Cope has applied the name rhachitomous, and is of great interest as showing the wide distribution of these primitive forms in this early period of the world's history.

CLASS V.—PISCES.

I.—TERTIARY.

Pliocene and (?) upper miocene.—With one exception all the remains of Siwalik fishes have been obtained from the upper division of the series. Teeth of a species of *Carcharias* apparently allied to the existing Indian *C. glaucus* and *C. gangeticus* occur sparingly in the Siwaliks of the Punjab; and it is interesting to notice that the latter shark which frequently ascends a considerable distance up tidal rivers, is found living in inland lakes in the Fiji islands. The large-toothed *Carcharodon* is represented by a single tooth from the Siwaliks of lower Burma. In the Teleostei, as might have been expected, nearly all the Siwalik forms belong to the families *Ophiocephalidæ* and *Siluridæ*, which are now so abundantly represented in the freshwaters of India. Of the former family the type genus *Ophiocephalus* is represented by two species, one considerably larger than the other. This genus is mainly characteristic of the Oriental region, although one or two species occur in Africa, and no other fossil forms are known. In the *Siluridæ* the genus *Clarias*, which is confined to the Oriental region and Africa, is represented by *C. falconeri*; while one species of the allied African genus *Heterobranchus* has been described under the name of *H. palæindicus*. An imperfect cranium from the Punjab has been provisionally referred to the genus *Chrysichthys*, now characteristic of tropical Africa, under the name of *C. theobaldi*; and if rightly determined affords additional evidence of the African affinities of the Siwalik fish-fauna, so strongly exemplified by the occurrence of *Heterobranchus*. The existing *Macrones aor* of the Indian and Burmese rivers has existed there since the Siwalik period; while the characteristic Oriental genus *Rita* was represented by a large species from the Punjab to which the name *R. grandiscutata* has been applied. Of the widely-distributed genus *Arius* there is evidence of two species; one being very large and apparently allied to the existing *A. latiscutatus* of West Africa; while the other is smaller, and its generic reference provisional; the latter is known only by palatines from the Punjab and Sind. Finally more numerous remains belonging to the huge *Bagarius yarrelli* now inhabiting the larger rivers of India and Java have been obtained from the typical Siwalik hills. The genus *Bagarius* is a comparatively old one, since remains

from the older tertiaries of Padang in Sumatra have been described under the name of *B. gigas*. The last Siwalik fish belongs to the family *Cyprinodontidæ*, but its generic position has not yet been determined; the one specimen is preserved in the Museum of Science and Art, Dublin.

Eocene.—From the eocene of the Andaman Islands and Ramri Island on the Arakan coast there have been obtained two teeth of a large *Diodon*, named *D. foleyi;* and from the occurrence of *D. hystrix* off these coasts at the present time, it may be assumed that the genus has lived there since the eocene. Remains of this genus have been obtained from the miocene of Malta and other parts of Europe. Undetermined cycloid scales have been obtained from the eocene of Thyetmyo in Burma. From the eocene of Kach the dental plate of a species of eagle-ray has received the name of *Myliobatis curvipalatus;* while from the neighbourhood of Kohat, in the Punjab, a single incisor of a sparoid fish, named *Capitodus indicus*, has been obtained. This genus was previously known only from the miocene of the Vienna basin and Silesia, and is allied to the living *Sargus*. All the above specimens of teeth are in the collection of the Indian Museum. A fragment of chert from Sind, which is of eocene age, in the British Museum (No. 23284), bears the impress of part of the cranial rostrum of a sword-fish of the genus *Cœlorhynchus*, which is found in the Bracklesham beds and the London-clay of Sheppey. The above-mentioned bed in the Salt-range from which the Chelonians were obtained, has also yielded some undescribed fish-teeth which are said to belong to the genera *Lamna, Otodus, Hemipristis, and Capitodus.*

II.—MESOZOIC AND PALÆZOIC.

Cretaceous.—A few remains of fishes have been obtained from the higher cretaceous Lameta group, but are not determined, though it has been suggested that some of them may belong to the genus *Sphyrænodus*, of the cretaceous of Europe. From the three groups of the middle and upper cretaceous Trichinopoli series the remains of several species of sharks have been obtained; these comprise the genera *Corax* (probably not really different from *Carcharias*), *Lamna* (including *Oxyrhina*), *Odontaspis*, and *Otodus;* all these genera occur in the cretaceous of Europe, the species *Corax pristodontus* being common to the two regions. The widely-distributed upper cretaceous *Ptychodus latissimus* has left a few remains; and it may be well to observe that the genus *Ptychodus*, which has been usually referred to the cestraciont sharks, appears really to be a ray.[1] One fragment indicates a ganoid which has been provisionally identified with the European genus *Pycnodus;* while another member of the same order is referred to *Sphærodus* with the name of *S. rugulosus*. The only known teleostean fish from this formation belongs to the European cretaceous genus *Enchodus*, and has received the name *E. serratus;* the genus is now referred to the family *Trichiuridæ*, of which the scabbard-fish (*Lepidopus*) is a well-known example.

Gondwana system.—From the Kota group, whose fauna presents a decided liassic facies, nine species of ganoids have been determined; many of them on nearly complete specimens. The *Dapedidæ*[2] are represented by *Tetragonolepis* (three

[1] See a paper by Mr. A. Smith-Woodward in the Quart. Journ. Geol. Soc. Vol. XLIII.
[2] *Stylodontidæ* of Günther.

species) and the closely allied *Dapedius* (one species); both genera being in Europe exclusively jurassic, and especially characteristic of the lias. The other family is the *Lepidotidæ*,[1] of which there are five species belonging to the type genus *Lepidotus*, which ranges from the lias to the cretaceous, and apparently survived into the eocene, if the species from that formation should not prove to be a *Lepidosteus*. The remaining ganoid is not generically determined. In the Maleri group, the fauna of which shows an upper triassic facies, three species of the genus *Ceratodus* have been determined, and respectively named *C. hislopianus*, *C. hunterianus*, and *C. virapa*; the latter being considered closely allied to *C. polymorphus* of the upper trias (rhætic) of Bristol. At the present day the genus inhabits the rivers of Queensland, and in Europe is found fossil from the upper trias (keuper) to the jura. The specimens are in the Indian Museum.

Productus-limestone.—The earliest Indian Vertebrata of which there is any record are known merely by a few specimens of teeth and spines obtained from the palæozoic rocks of the Salt-range in the Punjab. The system from which these remains were obtained is termed the 'Productus-Limestone,' and is considered to correspond to the permian and upper carboniferous of Europe. A peculiar genus of ganoid is described, upon the evidence of a single tooth, under the name of *Sigmodus dubius*; this tooth being of an elongated conical form and much resembling the teeth of certain saurians. Other small teeth have been doubtfully referred to the ganoid genus *Saurichthys*, with the name of *S.* (?) *indicus*; the genus belongs to the same family as *Holoptychius*, and is characteristic of the devonian and carboniferous of Europe. Of the cochliodonts, referred by Günther to the *Cestraciontidæ*, there are two peculiar genera, each represented by a single species, namely, *Pœcilodus paradoxus* and *Psephodus indicus*; the tooth of the former is of the flattened cestraciont type. Of other Selachoidei with crushing teeth, six genera have been named, some from the evidence of teeth, and others from spines; but in view of certain modern discoveries, it is not impossible that in some cases distinct genera have been formed from the different remains of the same animal. Of these the new genus *Helodopsis*, allied to the European *Helodus*, has been formed for the reception of two teeth, which have been referred to distinct species under the respective names of *H. elongata* and *H. abbreviata*. A fragmental tooth, too imperfect for specific determination, has been referred to the common European devonian and carboniferous genus *Psammodus*.[2] A fourth tooth, under the name of *P. indicus*, is referred to the European genus *Petalorhyncus*, which is very doubtfully separated from *Petalodus*. Teeth of two species of *Acrodus* have also been described, to one of which the name *A. flemingi* has been applied. Of the spines, three specimens are referred to the genus *Xystracanthus*, of the carboniferous of North America, under the name of *X. gracilis*, *X. major*, and *X. minor*; the possibility of these specimens belonging to some species of *Helodopsis* is, however, suggested. A fourth spine is referred to a genus, under the name of *Thaumatacanthus blanfordi*. As far as the evidence of these fishes goes, it is apparent that sharks with crushing teeth were the dominant forms in the Indian carboniferous seas, as well as in those of Europe and America. Most of the specimens noticed above are in the collection of the Indian Museum.

[1] *Sphærodontidæ* of Günther.

[2] This genus may eventually prove to be a ray.

SYSTEMATIC CHRONOLOGICAL LIST OF SPECIES.

I. TERTIARY AND POST-TERTIARY.

1. PLEISTOCENE AND (?) LATER BEDS.

a. Turbary and alluvium of Madras,[1] *Assam, etc.*

MAMMALIA	PRIMATES	† Macacus *sp.* (*cf.* rhesus [*F. Cuv.*]).
		sp. (*cf.* sinicus [Linn.])
	UNGULATA	Elephas indicus, *Linn.*
		† Rhinoceros unicornis, *Linn.*
		† Sus cristatus, *Wagner.*

b. Caverns of the Karnul district, Madras.

PRIMATES	Semnopithecus entellus (*Dufresne*).
	Cynocephalus, *sp.*
CARNIVORA	Felis tigris (*or* ? leo) *Linn.*
	—— ? pardus, *Linn.*
	—— chaus, *Güldenst.*
	—— rubiginosa, *Geoffr.*
	Hyæna crocuta (*Erxl.*).
	Viverra karnuliensis, *Lyd.*
	Prionodon (?), *sp.*
	Herpestes griseus, *Desm.*
	——— fuscus, *Waterh.*
	——— nipalensis, *Gray.*
	Ursus labiatus, *Blainv.*
INSECTIVORA	Sorex, *sp.*
CHIROPTERA	Taphozous saccolæmus, *Temm.*
	Phyllorhina diadema (*Geoffr.*).
UNGULATA	Equus asinus, *Linn.*
	——— *sp. a.*
	Rhinoceros karnuliensis, *Lyd.*
	Bos *or* Bubalus, *sp.*
	Boselaphus tragocamelus (*Pall.*).
	Genus non. det.
	Gazella bennetti (*Sykes*).
	Antilope cervicapra (*Linn.*).
	Tetraceros quadricornis (*Blainv.*).
	Cervus aristotelis, *Cuv.*
	——— axis, *Erxl.*
	? Cervulus muntjac (*Zimm.*).
	Tragulus (*cf.* meminna [*Erxl.*]).
	Sus cristatus, *Wagner.*
	— karnuliensis, *Lyd.*
RODENTIA	Sciurus macrurus, *Hardw.*
	Gerbillus indicus (*Hardw.*).
	Nesokia bandicoota (*Bech.*).
	——— kok, *Gray.*
	Mus mettada (*Gray.*).
	—— platythrix, *Sykes.*
	—— *sp. var.*
	Golunda ellioti, *Gray.*

[1] The Madras forms are indicated by †.

	RODENTIA—*contd.*	Hystrix crassidens, *Lyd.*
		Atherura karnuliensis, *Lyd.*
		Lepus (*cf.* nigricollis, *F. Cuv.*).
	EDENTATA	Manis gigantea, *Illiger.*
AVES .	ACCIPITRES	Neophron percnopterus (*Linn.*).
		? Milvus *or* Circus, *sp.*
	STRIGES .	Ketupa ceylonensis (*Gmelin*).
		Bubo coromandus (*Lath.*).
	GALLINÆ	Francolinus pictus (*Jard. and Selby.*).
		——— pondicerianus (*Gmelin*).
	ALECTORIDES . .	Grus (*cf.* communis, *Bechst.*).
	HERODIONES . .	Ibis melanocephala (*Lath.*).
REPTILIA .	CROCODILIA . .	Crocodilus, *sp.*
	LACERTILIA . .	Varanus dracæna (*Shaw.*).
	OPHIDIA . .	Python molurus (*Linn.*).
		Naia tripudians (*Merr.*).
		Ptyas mucosus (*Linn.*).
AMPHIBIA .	BATRACHIA . .	Bubo (*cf.* melanostictus, *Schneid.*).

c. The Kistna Valley.

MAMMALIA .	UNGULATA . .	Rhinoceros deccanensis, *Foote.*
		Bos *or* Bubalus, *sp.*

d. The Narbada, Jamna, Godaveri, and Pemganga Valleys.

	CARNIVORA . .	Ursus namadicus, *F. & C.*
		Felis (? tigris, *or* leo, *Linn.*).
	UNGULATA . .	Elephas namadicus, *F. & C.*
		——— ganesa, *F. & C.*
		? ——— insignis, *F. & C.*
		Rhinoceros unicornis, *Linn.*
		——— namadicus, *F. & C.*
		Equus namadicus, *F. & C.*
		Bubalus buffelus (*Blum.*).
		Bos namadicus, *F. & C.*
		Leptobos fraseri, *Rüt.*
		Boselaphus namadicus (*Rüt*).
		Antilope cervicapra, *Pall.*
		Cervus aristotelis, *Cuv.*
		? ——— duvaucelli, *Cuv.*
		——— porcinus, *Zimm.*
		Sus cristatus, *Wagn.*
		Hippopotamus palæindicus, *F. & C.*
		——— namadicus, *F. & C.*
	RODENTIA . .	Muridæ, *gen. non. det.*
REPTILIA .	CROCODILIA . .	Crocodilus, (?) *sp.*
	CHELONIA . .	Pangshura flaviventris, *Günth.*
		Batagur (*cf.* dhongoka, *Gray.*).
		Trionyx gangeticus, *Cuv.*

2. PLIOCENE AND (?) UPPER MIOCENE.

a. Hundes Valley in Tibet.

MAMMALIA .	CARNIVORA . .	Hyæna, *sp.*
	UNGULATA . .	Hipparion, *sp.*
		Pantholops, (?) hundesiensis, *Lyd.*
		Capra, *sp.*
		Ovis, (?) *sp.*

b. Upper and Lower Siwaliks.[1]

MAMMALIA .	PRIMATES . . .	‖	Troglodytes sivalensis, *Lyd.*
			Simia, *sp.*
			Semnopithecus palæindicus, *Lyd.*
		‖	Macacus sivalensis, *Lyd.*
			Cynocephalus subhimalayanus (*Myr.*),
			———— falconeri, *Lyd.*
	CARNIVORA . . .		Machærodus sivalensis (*F. & C.*).
			———— palæindicus, *Bose.*
			Felis cristata (*F. & C.*).
			—— (?Cynælurus) brachygnatha, *Lyd.*
		‖	—— *sp. a.*
		‖	—— *sp. b.*
			—— subhimalayana, *Brown.*
		‖	?Ælurogale sivalensis, *Lyd.*
		‖	Æluropsis annectans, *Lyd.*
			Hyæna felina, *Bose.*
			——— colvini, *Lyd.*
			——— sivalensis, *Bose.*
		‖	——— macrostoma, *Lyd.*
			——— *sp.*
		‖	Lepthyæna sivalensis, *Lyd.*
			Viverra bakeri, *Bose.*
			——— durandi, *Lyd.*
			Canis cautleyi, *Bose.*
			——— curvipalatus, *Bose.*
		†	Amphicyon palæindicus, *Lyd.*
		‖	Hyænarctos palæindicus, *Lyd.*
		‖	———— punjabiensis, *Lyd*
			———— sivalensis, *F. & C*
		‖	Ursus theobaldi, *Lyd.*
			Mustela, *sp.*
			Mellivora sivalensis, *F. & C.*
		‖	——— punjabiensis, *Lyd.*
		‖	Mellivorodon palæindicus, *Lyd.*
			Lutra palæindica, *F. & C.*
		‖	—— bathygnatha, *Lyd.*
			—— sivalensis, *F. & C.*
		‖	Hyænodon indicus, *Lyd.*
	UNGULATA .		Elephas hysudricus, *F. & C.*
			——— planifrons, *F. & C.*
			——— ganesa, *F. & C.*
			——— insignis, *F. & C.*
			——— bombifrons, *F. & C.*
			——— clifti, *F. & C.*
	Prob[illegible]cidea.	†	Mastodon latidens, *Clift.*
		‡	———— cautleyi, *Lyd.*
		‖	———— punjabiensis, *Lyd.*
		‡	———— perimensis, *F. & C.*
			———— sivalensis, *Cautley.*
		†	———— pandionis, *Falc.*
			———— falconeri, *Lyd.*
		††	———— angustidens, *Cuv.*

[1] Forms which occur in the lower Siwaliks of Sind and the neighbouring regions, as well as in the upper Siwaliks, are marked †; and those peculiar to the lower Siwaliks ††. Forms confined to the Punjab are marked ‖; those found only in Perim Island ‡, and those peculiar to Burma *.

UNGULATA—*contd.*

‖† Dinotherium sindiense, *Lyd.*
———— indicum, *Falc.*

Prissodactyla.

* (?) Tapirus, *sp.*
Equus sivalensis, *F. & C.*
——— namadicus, *F. & C.*
Hipparion antilopinum, *F. & C.*
——— theobaldi, *Lyd.*
‖ ——— punjabiensis, *Lyd.*
‡ ——— *sp.* (feddeni, *Lyd.*)
Rhinoceros platyrhinus, *F. & C.*
——— palæindicus, *F. & C.*
† ——— sivalensis, *F. & C.*
——— perimensis, *F. & C.*
†† ——— blanfordi, *Lyd.*
† Chalicotherium, sivalense, *F. & C.*

Artiodactyla.

Bos acutifrons, *Lyd.*
—— planifrons, *Lyd.*
—— (?) platyrhinus, *Lyd.*
Bison sivalensis, *Falc.*
Bubalus platyceros, *Lyd.*
——— (*cf.* buffelus [*Blum.*]).
——— occipitalis (*Falc.*).
——— acuticornis (*Rüt.*).
——— antilopinus (*F. & C.*).
Leptobos falconeri, *Rüt.*
Bucapra daviesi, *Rüt.*
Capra sivalensis, *Lyd.*
—— perimensis, *Lyd.*
—— *sp.*
Ovis (?) *sp.*
‡ Strepsiceros (?) falconeri, *Lyd.*
Oreas (?) latidens, *Lyd.*
Boselaphus, *sp.*
Hippotragus sivalensis, *Lyd.*
Gazella porrecticornis, *Lyd.*
‖ ——— *sp.*
Cobus (?) palæindicus, *Lyd.*
——— (?) patulicornis, *Lyd.*
Tetraceros daviesi, *Lyd.*
(?) Cephalopus, *sp.*
Alcelaphus palæindicus (*Falc.*).
Sivatherium giganteum, *F. & C.*
‖ Hydaspitherium grande, *Lyd.*
‖ ———— megacephalum, *Lyd.*
‡ Bramatherium perimense, *Falc.*
Helladotherium duvernoyi, *Wag.*
‖* Vishnutherium, iravaticum, *Lyd.*
Giraffa sivalensis (*F. & C.*)
Cervus triplidens, *Lyd.*
——— sivalensis, *Lyd.*
——— simplicidens, *Lyd.*
? ‖ Moschus, *sp.*
‖ Palæomeryx sivalensis, *Lyd.*
Camelus sivalensis, *F. & C.*
——— antiquus, *Lyd.*
Tragulus sivalensis, *Lyd.*

UNGULATA—*contd.*

Artiodactyla.

Dorcatherium majus, *Lyd.*
——— minus, *Lyd.*
† Chœromeryx silistrensis (*Pent*).
†† Agriochœrus (?) *sp.*
†† Hemimeryx blanfordi, *Lyd.*
Merycopotamus dissimilis, *F. & C.*
——— nanus, *Lyd.*
‖ ——— pusillus, *Lyd.*
†† Hyopotamus palæindicus, *Lyd.*
†† ——— giganteus, *Lyd.*
† Anthracotherium silistrense (*Pent*).
†† ——— hyopotamoides, *Lyd.*
——— *sp. a.*
——— *sp. b.*
Tetraconodon magnus, *Falc.*
†† Hyotherium sindiense, *Lyd.*
‡ ——— perimense, *Lyd.*
Hippohyus sivalensis, *F. & C.*
——— *sp.*
Sanitherium schlagintweiti, *Myr.*
Sus giganteus, *F. & C.*
‖ —— titan, *Lyd.*
—— falconeri, *Lyd.*
† —— hysudricus, *F. & C.*
‖ —— punjabiensis, *Lyd.*
—— *sp.*
‖ Listriodon pentapotamiæ, *Falc.*
‖ ——— theobaldi, *Lyd.*
* Hippopotamus iravaticus, *F. & C.*
——— sivalensis, *F. & C.*

RODENTIA . . Nesokia, *sp.*
Rhizomys sivalensis, *Lyd.*
Hystrix sivalensis, *Lyd.*
Lepus, *sp.*

EDENTATA . . †† Macrotherium sindiense, *Lyd.*

AVES

STEGANOPODES . Phalacrocorax (?) *sp.*
Pelecanus cautleyi, *Dav.*
——— (?) sivalensis, *Dav.*

HERODIONES . . Leptoptilus falconeri (*M. Ed.*).
Gen. non. det.

ANSERES . . . ? Mergus, *sp.*

STRUTHIONES . . Struthio asiaticus, *M. Ed.*

REPTILIA

CHELONIA . . Colossochelys atlas, *F. & C.*
Genus non det, sp. a.
——— *sp. b.* (? *Cautleya annuliger* Theob.)
——— *sp. c.*
——— *sp. d.*
‖ Clemmys sivalensis (*Theob.*).
‖ ——— hydaspica, *Lyd.*
‖ ——— theobaldi, *Lyd.*
‖ ——— punjabiensis, *Lyd.*
——— *sp. a.*
‡ ——— watsoni, *Lyd.*
——— palæindica, *Lyd.*

	CHELONIA—*contd.*		Clemmys (?) *sp. b.*
			Pangshura flaviventris, Günth. (?)
			——— *sp. a.*
			Batagur falconeri, *Lyd.*
			——— bakeri, *Lyd.*
			——— durandi, *Lyd.*
			——— cautleyi, *Lyd.*
			Genus non det. (? Geoemyda) *sp.*
			Emyda vittata, *Pet.*
			——— lineata, *Lyd.*
			——— sivalensis, *Lyd.*
			——— palæindica, *Lyd.*
			Trionyx, *sp.*
			Chitra indica, *Gray.*
	CROCODILIA .		Crocodilus sivalensis, *Lyd.*
		‡	——— palæindicus, *Falc.*
			Garialis gangeticus (*Gmel.*).
			——— hysudricus, *Lyd.*
		††	——— curvirostris, *Lyd.*
			——— leptodus (*F. & C.*).
		††	——— pachyrhynchus, *Lyd.*
			Rhamphosuchus crassidens (*F. & C.*).
	LACERTILIA . .		Varanus sivalensis, *Falc.*
	OPHIDIA . .	‖	Python molurus, *Linn.*
		‖ †	——— *sp.*
PISCES	. CHONDROPTERYGII .	‖	Carcharias, *sp.*
		*	Carcharodon, *sp.*
	ACANTHOPTERYGII .		Ophiocephalus, *sp. a.*
			——— *sp. b.*
	PHYSOSTOMI . .		Clarias falconeri, *Lyd.*
			Heterobranchus palæindicus, *Lyd.*
		‖	Chrysichthys (?) theobaldi, *Lyd.*
			Macrones aor, *B. Ham.*
		‖	Rita grandiscutata, *Lyd.*
			Arius, *sp. a.*
		‖ †	——— *sp. b.*
			Bagarius yarrelli (*Syk.*).
			Cyprinodontidæ, gen. non. det.

3. MIOCENE.

MAMMALIA .	. UNGULATA . .		Rhinoceros sivalensis, *var.* gajensis, *Lyd.*

4. EOCENE.

" . .	" . .	(?)	Palæotherium, *sp.*
			Gen. non. det. (*Artiodactyle*).
REPTILIA .	. CHELONIA . .		Platemys leithi (*Carter*).
			Hemichelys warthi, *Lyd.*
			Gen. non. det.
	CROCODILIA .		*Gen. non. det.*
AMPHIBIA .	BATRACHIA .		Oxyglossus pusillus (*Owen*).
			——— (?) *sp.*
PISCES .	CHONDROPTERYGII		Myliobatis curvipalatus, *Lyd.*
	ACANTHOPTERYGII		Capitodus indicus, *Lyd.*
			Cœlorhynchus, *sp.*
	PLECTOGNATHI		Diodon foleyi, *Lyd.*

II.—MESOZOIC AND PALÆOZOIC.

1.—CRETACEOUS.

REPTILIA		DINOSAURIA	Megalosaurus, *sp.*
			Titanosaurus blanfordi, *Lyd.*
			——— indicus, *Lyd.*
			Gen. non det.
		CHELONIA	*Gen. non det.*
		CROCODILIA	*Gen. non det.*
		ICHTHYOSAURIA	Ichthyosaurus indicus, *Lyd.*
PISCES	*Palæichthyes.*	CHONDROPTERYGII	Corax incisus, *Eger.*
			——— pristodontus, *Agas.*
			Lamna complanata, *Eger.*
			——— sigmoides, *Eger.*
			——— (Oxyrhina) triangularis, *Eger*
			——— *sp.*
			Odontaspis constrictus, *Eger.*
			——— oxypeion, *Eger.*
			Otodus basalis, *Eger.*
			——— divergens, *Eger.*
			——— marginatus, *Eger.*
			——— minutus, *Eger.*
			——— nanus, *Eger.*
			——— semiplicatus, *Eger.*
			Ptychodus latissimus, *Agas.*
		GANOIDEI	Pycnodus (?) *sp.*
			Sphærodus rugulosus, *Eger.*
		ACANTHOPTERYGII	Enchodus serratus, *Eger.*

2.—GONDWANA (*Jura to Permian.*)[1]

REPTILIA	DINOSAURIA	†	Epicampodon indicus (*Hux.*).
		‡	*Gen. non det.*
	CROCODILIA	(?) *	*Gen. non det.*
		‡	Parasuchus hislopi, *Lyd.*
		‡	Belodon, *sp.*
	ANOMODONTIA	‡	Hyperodapedon huxleyi, *Lyd.*
		†	Dicynodon orientalis, *Hux.*
		†	——— *sp.*
	PLESIOSAURIA	*	Plesiosaurus indicus, *Lyd.*
AMPHIBIA	LABYRINTHODONTIA	†	Gonioglyptus longirostris, *Hux.*
		†	——— huxleyi, *Lyd.*
		†	Glyptognathus fragilis, *Lyd.*
		†	Pachygonia incurvata, *Hux.*
		‡	——— *sp.*
		‡	Mastodonsaurus, *sp.*
		‡	*Gen. non det.*
		‖	Brachyops laticeps, *Owen.*
		‖	Gondwanosaurus bijoriensis, *Lyd.*
PISCES	GANOIDEI		Ceratodus hislopianus, *Old.*
			——— hunterianus, *Old.*
			——— virapa, *Old.*
			Lepidotus breviceps, *Eger.*
			——— calcaratus, *Eger.*
			——— deccanensis, *Eger.*

[1] The older unfossiliferous beds are probably partly carboniferous. In the table the Maleri and South Rewah forms are indicated by a ‡; those from the Chari and Umia groups by an *; those from the Panchet beds by a †, and those from the Bijori and Mangli by a ‖.

		Lepidotus longiceps, *Eger.*
		——— pachylepis, *Eger.*
		Dapedius egertoni, *Syk.*
		Tetragonolepis analis, *Eger.*
		——— oldhami, *Eger.*
		——— rugosus, *Eger.*
		Gen. non det.

3.—PRODUCTUS-LIMESTONE (*Permian to Carboniferous*).

PISCES	GANOIDEI . . .	Sigmodus dubius, *Waag.*
		Saurichthys (?) indicus, *De Kon.*
	CHONDROPTERYGII	Helodopsis elongata, *Waag.*
		——— abbreviata, *Waag.*
		Psammodus, *sp.*
		Pœcilodus paradoxus, *Waag.*
		Psephodus indicus, *Waag.*
		Acrodus flemingi, *De Kon.*
		Petalorhynchus indicus, *Waag.*
		Xystracanthus gracilis, *Waag.*
		——— major, *Waag.*
		——— giganteus, *Waag.*
		Thaumatacanthus blanfordi, *Waag.*

APPENDIX.

Mastodonsaurus *from N. S. Wales.*—In 'Nature' of December 16th, 1886, is published a note recording the reported occurrence in the Haukesbury group of the Gondwánas of New South Wales of a ***Mastodonsaurus*** apparently allied to ***M. giganteus*** of the European Muschelkalk and Keuper. This determination (which was made by comparison with a cast of the Stuttgart skull, and is therefore probably correct) is of great interest in respect to the occurrence of an allied member of the genus in the Denwa group.[1]

The recent observations of Mr. Oldham[2] indicate that the Haukesbury beds are probably separated by an unconformity from the underlying Newcastle group, and that the latter is nearly related in time with the Damuda series (Ranigunj, Bijori, and Barakar groups). The presence in both the Denwa and Haukesbury groups of an allied (or perhaps identical) species of ***Mastodonsaurus***, the restricted vertical distribution of that genus in Europe being borne in mind, suggests very strongly the approximate equivalence of these groups. The Denwa group belongs to a considerably higher horizon than the Damuda series[3] (Newcastle group), and the elevation of the Haukesbury beds to the same approximate level would accord with the unconformity between the latter and the Newcastle group.

With regard to the homotaxy of the Indo-Australian Gondwánas with the European succession, it may be observed that the Australian sequence rests on marine beds correlated by Dr. Waagen[4] with the lower carboniferous, and that the three groups[5] below the Newcastle consequently correspond to the upper carboniferous; in which division, according to Mr. Oldham's identifications, may likewise be included the Indian Talchirs and the Victorian Bacchus Marsh beds.[6] This being so, the Newcastle and Damudas might correspond to the permian; the Panchets (which might roughly represent the interval between the Newcastle[7] and Haukesbury) to the lower trias; and the Indian Denwa and Maleri and the Australian Haukesbury and Wianamatta to the middle and upper divisions of the latter.

How closely such an homotaxial sequence corresponds with the European horizons indicated by the Gondwána vertebrates of India has been already noticed by myself;[8] and this correspondence is strengthened by the evidence of the Haukesbury ***Mastodonsaurus***. It is true that a certain discrepancy is introduced by the occurrence in the latter beds of ***Palæoniscus*** and ***Myriolepis***, but since one species of the former is found in the European upper trias, there is no reason, especially when we recall the persistence in Australia of ***Ceratodus***, why the latter genus should not also have survived in that country to the same epoch.

[1] *Supra*, p. 68.
[2] *Supra*, Vol. XIX. p p. 40, 46.
[3] See table on p. 108 of the 'Manual of the Geology of India.'
[4] *Supra*, Vol. XIX. p. 35.
[5] *Ibid.* p. 40, note.
[6] *Ibid.* p. 43.
[7] Dr. Waagen in the passage cited followed Dr. Feistmantel's erroneous view of correlating the Bacchus-Marsh with the Haukesbury beds, and of removing the Newcastle from the Damudas, which are regarded as probably permian.
[8] *Ibid.* p. 133.

Note on the Echinoidea *of the* Cretaceous *series of the* Lower Narbadá Valley, *with remarks upon their Geological age, by* PROFESSOR P. MARTIN DUNCAN, F.R.S., &C., *November 1886.*

CONTENTS.—History of the geological and palæontological researches amongst the Cretaceous rocks of the Bág district — A criticism of the palæontology and geological results given in "The Geology of the Lower Narbada Valley, by P. N. Bose, B.Sc., Lond., F.G. S.," in Memoirs of the Geological Survey of India — Lists of the Echinoidea — Deductions — Description of New Species and notices of the forms already known — Description of Plate.

In 1865 my attention was directed to a small collection of Echinodermata, Mollusca, and other fossils in the Museum of the Geological Society of London, which had been presented by Dr. H. Carter, F.R.S. The specimens came from strata near Bág in the Lower Narbadá Valley, and they were collected by Captain Keatinge.

The existence of at least eight European types in the small collection, impressed me very much, as did also their unmistakable Upper Greensand facies. A correspondence with Dr. Carter led to the examination of the fossils from S. E. Arabia, which had been collected by him from strata which he considered to be of the same age as the Indian beds and which presented the same mineralogical characters. The specimens from S. E. Arabia were more numerous than those of the Bág beds, and out of eight species of Echinodermata, seven were recognized as European Upper Greensand forms. The Mollusca, a Brachiopod and a Coral from Bág told the same story of the persistence, with slight variation, into the East, of species such as *Salenia scutigera, Pygaster truncatus, Epiaster distinctus,* &c., *Pecten quadricostatus, Neithia alpina, Rhynchonella depressa* and *Thamnastræa decipiens.* The commonest fossils were referable to *Hemiaster Cenomanensis,* Cott., and *Hemiaster similis,* d'Orb. A communication was published in the Quar. Jour. Geol. Soc., 1865, Vol. XXI, page 348, dealing with the collections and asserting the Upper Greensand age of the somewhat widely separated groups of strata.

In 1866 Messrs. Blanford and Wynne made as satisfactory a survey of the Lower Valley of the Narbadá as was possible, without the aid of a perfect geographical map. (Mem. Geol. Sur. Ind. VI, pages (207)—(219), (294)—(302), also Blanford, Geol. Bombay, Rec. Geol. Sur. Ind. Vol. V, pt. 3, p. 82. 1872.)

The Surveyors stated that the Cretaceous strata which had been called the Bág beds, rested in one place unconformably on an outlier of the Upper Gondwána series, and that there was a succession, from below upwards, of sandstone and conglomerate, 20 feet, Nodular limestone, nearly unfossiliferous, 20 feet, Argillaceous limestones, fossiliferous, 10 feet, and Coralline limestone (Bryozoan), 10 to 20 feet.

The beds were described and their relation to the overlying Deccan trap explained; moreover it was discovered that the fossils which had come under my notice had been obtained from the Argillâceous limestone. Blanford accepted the particular geological horizon which I considered the species indicated.

In 1868, the Upper Greensand horizon was recognized from the fossils, which were collected by Mr. Holland and subsequently by Mr. Bauerman, in the area of Sinai (Quar. Jour. Geol. Soc., Vol. 23, read December 1866, page 38 (not noticed in the list of contents) and Quar. Jour. Geol. Soc., Vol. 25, page 44, read December 9, 1868, published in 1869).

Two of the species of Echinoidea which had been noticed at Bág and in S. E. Arabia besides many well known Upper Greensand forms were found in one of the collections from Sinai, and in the second collection no less than 13 out of 24 species were recognized as being members of the strata above the Gault and below the horizon of the White Chalk in N. Africa (Algeria). Eight species were found to be common to the Sinai range and Tih and the Upper Greensands of Europe.

In 1873, the late Ferd. Stoliczka had his great work on the Echinodermata of the Cretaceous rocks of S. India published in the Palæontologia Indica, and it became evident that this interesting series of strata did not contain the commonest species of the Echinoidea of Bág and the Arabian districts. Yet an Upper Greensand horizon was clearly identified in S. India, from the facies of the Corals and some of the mollusca, moreover there were European Cenomanian species present. The remarkable fauna of the three groups of Cretaceous strata in S. India had been the source of much consideration amongst European palæontologists, and there were hopes expressed that a further search for fossils would be made amongst the Cretaceous rocks of the Narbadá Valley, so as to obtain the requisite data for a better comparison of the distant strata.

Stoliczka considered that the strata in S. India represented the European Cenomanian, Turonian and Senonian, to the top of the White Chalk. The Ammonites of the lower divisions gave a Gault facies, but Stoliczka noticed that the species which gave the facies had a great vertical distribution in Europe and were found in both Gault and Cenomanian.

In 1880, Mr. P. N. Bose, B.Sc., Lond., F.G.S., of the Indian Geological Survey, was ordered to proceed to the Lower Narbadá Valley and to pay during his survey special attention to the fossiliferous strata and igneous rocks. Mr. Bose had the advantage of an excellent geographical map, and the results of his survey were published in the Memoirs of the Geological Survey of India, Vol. xxi, pt. I. 1884.

Mr. Bose writes with great modesty, not unflavoured with some critical sharpness, when dealing with his predecessors in the stratigraphical part of his work, and he also most straightforwardly asserts his shortcomings as a palæontologist. He states that his determinations of species were "roughly done," and that he availed himself of the assistance of the most careful palæobotanist Herr Feistmantel.

The lists of species published by Mr. Bose are those of the specimens which he collected; he did not avail himself of the collection made, years before, by Keatinge and which is in the Museum at Calcutta, nor did he include the species which had been described by me in the communication already noticed. But in the lists it will be noticed that Mr. Bose places certain forms "taken on the authority of Dr. Duncan's identification." This is hardly correct, for I did not see Mr. Bose's collection, neither did I identify any species for him. I identified the species he names in the collection of the Geological Society, but that is quite another matter.

The succession of strata belonging to the Cretaceous formation in the Lower Narbadá area is according to Mr. Bose, at the bottom—

1. A sandstone, "The Nimar," conglomeratic at the base and fine-grained at the top except where in places an oyster bed is found.

2. Nodular-limestone.

3. The calcareous marl, of Deola and Chirákhán.
4. Coralline-limestone (Bryozoan).
5. Lametas (fresh-water).

He confirms Blanford and Wynne's survey in reference to the conformity of the whole of the marine beds, and states, as they did, that the Lameta freshwater beds rest on the eroded surfaces of the underlying Cretaceous strata, and that the Deccan and Malwa Trap covers the Lametas and the eroded Cretaceous strata.

Mr. Bose found an Oyster bed on the top of the sandstone (page 33), and states that it was about a foot in thickness; it rests quite conformably upon some horizontal, extremely coarse grit stones of insignificant thickness and passes above, equally without break, into the lowest beds of the Upper Cretaceous limestone series (nodular limestone). "The species is near, so far as I can make out, to *Ostræa Leymerii*, an European Neocomian form." Now it is evident that this doubtful Ostræa is not restricted to the lower strata, for (page 33) it is stated:—"At Ghátiá the oyster bed passes under flesh coloured limestones with Bryozoa and bivalves, elsewhere met with in the nodular limestone, as well as with diminutive forms of the Ostræa just described [? mentioned] in much diminished numbers."

Mr. Bose proceeds (page 34):—"It may seem ridiculous to attempt to fix the age of a deposit, with any approach to precision, on the approximate identification of only one fossil and that, too, merely an oyster. But this bivalve is a very characteristic fossil of the deposits under consideration, and if it passes up to the overlying limestone, it does so in considerably diminished numbers, and as a rule in diminutive forms and dies out in the course of deposition." On page 34 it is further stated—"Now the nodular limestone, which contains a well defined marine fauna, will be shown in the next chapter to be on the horizon of the Gault or Albian of the European Cretaceous system. We may, therefore, ascribe the oyster-bearing beds, not without some show of probability, to a lower (neocomian) horizon. The oyster being closely allied to an European neocomian form adds strength to the supposition."

These extracts require no comment from a palæontologist except the suggestion that it is a pity that Mr. Bose did not understand the meaning of "a characteristic species," and that he did lean upon such an infirm support as an Oyster of doubtful identity. Unfortunately Mr. Bose states further on in his memoir that the age of the underlying sandstone is unsettled.

The Nodular-limestone is stated to be of Gault age and the list of species is given (page 37). No fossils of this zone had been examined by any one before Mr. Bose made his interesting collection. The fossils of the Deola and Chirákhán marl, which rests conformably upon the Nodular-limestone, which also is often, according to Mr. Bose, marly in its nature, are numerous, and there are 29 forms which Mr. Bose has distinguished generically and in some instances specifically. He assigns the horizon of the fauna to the Cenomanian "or" to use his expression "at about the same horizon," the Turonian being included.

The Coralline-limestone is said to rest conformably on the Marl, and Mr. Bose notices six forms, two of which he names generically, Ostræa and Rhynchonella, and the others he gives specific names to. This limestone is placed by Mr. Bose on the horizon of the Senonian, and as he compares it with the Arriálur series of S. India, it must be placed high up in the Upper Cretaceous series.

In a recapitulation and statement of general results (page 48), Mr. Bose tabulates his succession of deposits, and modifies his former statements slightly. The Nodular limestone is now placed in an Albian and partly Cenomanian series; the Marl is partly Cenomanian and partly Turonian and the Coralline is Senonian. He places the Lametas with the Corallines in the Senonian.

It will be observed that Mr. Bose considers that the Neocomian is present at the bottom of a conformable limestone series, which has about 80 feet of vertical measurement at the greatest, and probably much less, and which may be sub-divided into Albian, Cenomanian, and Senonian and that all the S. Indian Cretaceous strata are represented in Narbadá area.

It is also evident that Mr. Bose agrees in the main with me about the age of the Deola and Chirákhán Marl. One of his remarks, however, requires notice. It is stated (page 48)—"These conclusions would appear to be at variance with that suggested by Keatinge, worked out by Duncan and accepted by Blanford, *viz.*, that the Bág rocks (in the widest and hitherto accepted sense of the expression) are assignable to about the same horizon as the Upper Greensand, and must in consequence, as remarks Mr. Blanford, closely correspond to the Utátur group of S. India. But considering that the data upon which this inference was based were still more insufficient than those collated in this report, it in reality rather tends to corroborate than otherwise the homotaxy indicated here." The last part of the paragraph is incomprehensible, and it was with some regret that I read Mr. Bose's acknowledgment of the insufficiency of the palæontological data upon which he based his stratigraphical succession of the whole Cretaceous formation in the N. W. of the Peninsula.

It is clear that the fossils named by myself came from one part of the Cretaceous series, and it will be found that I did not include any other strata in the Upper Greensand horizon except those which yielded the forms which in my opinion were sufficient to stamp the horizon. I referred to the necessity for Captain Keatinge being held responsible for the stratigraphical position of the fossils I named, and as I found *Hemiaster Cenomanensis*, Cott., *H. similis*, d'Orb., *Nucleolites similis*, Desor, and *Echinobrissus subquadratus*, d'Orb., sp., besides *Neithea alpina*, d'Orb., *Pecten quadricostatus*, Sow., *Rhynchonella depressa*, Sow., and *Thomnastræa decipiens*, Mich. sp., all species, except one, found only in the Cretaceous series of Europe between the Gault and the Chalk within Flints in Europe I had no hesitation in generalizing. The general Upper Greensand age was, therefore, determined with the aid of sufficient data, and it referred to the strata out of which the fossils came and to no others as Mr. Bose would infer. I had no fossils from the Nodular-limestone nor from the Coralline beds.

Having studied Mr. Bose's memoir, and having failed to agree with his deductions, from the species which he had named, regarding the ages of the Bág series, I applied to the Director of the Geological Survey of India, H. B. Medlicott, Esq., F.R.S., for the loan of all the Echinoidea which he could get me from the Bág district, including Mr. Bose's collection and named specimens. My request was granted, and I have received the fossils and in addition a collection made by Mr. Blanford and the original specimens which were collected so many years since by Captain Keatinge from the Marl.

The following is a list of the species which I have determined and the particular group of strata from which each was derived :—

NAME.	GROUP OF STRATA.	FOREIGN SERIES.
1. *Cidaris Namadicus*, sp. nov.	Deola and Chirákhán Marl and Corallines.	......
2. *Salenia Fraasi*, Cott.	Deola and Chirákhán Marl	Lebanon, Cenomanian.
3. *Cyphosoma Cenomanensis*, Cott.	Deola and Chirákhán Marl and Corallines.	Europe Cenomanian.
4. *Othopsis Indicus*, sp. nov.	Deola and Chirákhán Marl	......
5. *Echinobrissus Goybeti*, Cott.	Deola and Chirákhán Marl	Lebanon, Cenomanian.
6. *Nucleolites similis*, var. d'Orb.	Deola and Chirákhán Marl, Corallines.	Chloritic Marl, Europe.
7. *Hemiaster Cenomanensis*, Cott.	Nodular limestone, Deola and Chirákhán Marl, Corallines.	Europe, Cenomanian.
8. *Hemiaster similis*, d'Orb.	Nodular limestone, Deola and Chirákhán Marl, and Corallines.	Europe, Cenomanian.

The two species of Hemiaster are the commonest fossils, and any number of them may be examined from *each of the three* divisions of the Bág beds. They are Cenomanian forms in Europe. This persistence of common species throughout the three groups of beds, to each of which Mr. Bose has given a different horizon, renders the possibility of there being an Albian, a Cenomanian, and a Senonian at Bág very doubtful, and the following table of the distribution of the Echinoidea in the strata of the Bág area will add to the impossibility of crediting the presence of the whole Middle and Upper Cretaceous series in the same locality :—

NAME.	NOD.-LIMESTONE.	MARL.	CORALLINE.
Cidaris Namadicus, sp. nov.	o	...	...
Salenia Fraasi, Cott.	o	...	o
Cyphosoma Cenomanense, Cott.	o	...	...
Orthopsis Indicus, sp. nov.	o	...	o
Echinobrissus Goybeti, Cott.	o	...	o
Nucleolites similis, d'Orb. var.	o	...	...
Hemiaster Cenomanensis, Cott.	...	...	...
Hemiaster similis, d'Orb.	...	...	...

There are no Albian forms in this list, nor are there any Senonian species, and it is perfectly evident from the evidence afforded by the Echinoidea, that the strata which yielded specimens to Captain Keatinge, and which were described in 1865, must be considered to be on the European Cenomanian horizon and on that which stretches through S. E. Arabia, Sinai, the Lebanon, and Algeria into Europe.

The study of the Echinoidea contradicts Mr. Bose's statements.

It will be noticed that in the lists of species three of those included in Mr. Bose's lists are wanting. Having examined the specimen which he attributed to *Cidaris Cenomanensis*, Cott., I find specific differences and a very remarkable one in the ornamentation of the test beyond the scrobicules of the primary tubercles, moreover the scrobicular margins are also not those of the European form. I consider, however, that Mr. Bose was justified in giving the name he did as he states "roughly," for the general shape and the nature of the ambulacra would lead anybody to place the species near to the French form. The species of Orthopsis was considered by

Mr. Bose to be the same as that described by Stoliczka from the Arriálur deposits of Southern India; but there are specific distinctions, and a new species has to be diagnosed. The third species is *Echinobrissus sub-quadratus*. Thanks to M. Cotteau, a species has been described in which there are the remarkable petaloid ambulacra which made me hesitate years since in placing the Bág form in the Neocomian *E. sub-quadratus*.

On carefully re-studying the collection of the Echinoidea given by Dr. Carter to the Geological Society and which was described in 1865, I find it only necessary to replace *Echinobrissus sub-quadratus* by *Echinobrissus Goybeti*, Cott. There is no reason for interfering with the determinations made of the mollusca, brachiopod, and coral; they are all Upper Greensand forms, but it must be understood that they came from the Deola and Chirákhán Marl.

In conclusion it is absolutely necessary to remark upon the palæontological proofs offered by Mr. Bose that the Coralline limestone and the Nodular limestone, the upper and lower beds in a conformable series, are on the Senonian and Albian horizons respectively.

The following are forms from the Coralline according to Mr. Bose, *Ostræa* sp., *Rhynchonella plicatiloides*, Stol., *Rhynchonella* sp., *Ceriopora dispar*, *Hemiaster similis*, and *H. Cenomanensis*. Mr. Bose remarks as follows (pp. 43-44):

"This number is perhaps too small to reason upon. But the disappearance of all the most characteristic forms of the underlying beds has to be noted; and the special prominence and abundance of forms which had occupied a very subordinate position in the fauna of the latter, indicate considerable changes of physical conditions, and consequently a proportionate lapse of time. The remarkable change in the mineral character also proves a corresponding alteration in the configuration of the cretaceous seas and therefore in the physical geography of the country from which the rivers derived their sediment. On these considerations, and on the strength of the fact that two of the most characteristic forms occur in the Arriálur division of the South Indian cretaceous series, I am inclined to correlate the Coralline limestone, of course roughly, with the latter."

Divested of useless matter the palæontology of the Coralline so far as it is known to Mr. Bose relates to four species, three of which are common in the underlying Deola and Chirákhán Marl, and the fourth, less commonly found, is the *Rhynchonella plicatiloides*, Stol. Two of the species occur also in the Nodular limestone. So there is no special abundance of forms which had occupied a subordinate position, and indeed the two Hemiasters are *the most prominent* of the species of the underlying strata !!! Which are the two characteristic forms of the Coralline limestone it is impossible to state, for none of the species given by Mr. Bose are characteristic of the beds, the whole of the named species being found in underlying strata. He states however that the two occur in the Arriálur strata of Southern India, so by a process of elimination it may be possible to understand which species are meant. The two Hemiasters are not found in Southern India and that leaves *Rhynchonella plicatiloides*, Stol., and *Ceriopora dispar*, Stol. Now the first mentioned is more common in the South Indian series *which underlies the Arriálur beds*, than in the Arriálurs themselves; so the form is not characteristic of the Arriálur. The Bryozoon is found in the Arriálur beds of Southern India and in no others there; but it is

not characteristic of the Coralline limestone, for it is in Mr. Bose's list of both of the underlying strata, and in fact it passes up from the Nodular limestone through the Marl into the Coralline limestone. After these considerations Mr. Bose's correlation must be regarded as too rough to be true. No sufficient evidence has been offered which will place the Coralline limestone on the Arriálur horizon.

With regard to the palæontology of the Nodular limestone, the supposed Albian: it is stated (Bose *op. cit.* p. 39) that the majority of the characteristic forms occur on the horizon of the "Étage Albien (Gault)" and "that therefore there need be little hesitation in considering the Nodular limestone homotaxial with it, as well as with the lowest group of the South Indian Cretaceous series, the Utáturs."

Firstly, the Utátur strata, so splendidly considered palæontologically by Stoliczka, are not of the Albian or Gault age.

Secondly, on studying Mr. Bose's list of species it appears that the solitary Ammonite is elsewhere found in a higher cretaceous horizon than the Gault; and that the three Gasteropoda specifically determined, all belong to higher horizons than the Utátur in Southern India. The Bryozoon is said to be the same which is found in the *highest* and not in the *lowest* of the Southern Indian series. The two Hemiasters are Cenomanian in Europe and are found throughout the Bág beds. The Lamellibranchiata are, according to Mr. Bose's rough determination, very remarkable. The Neocomian Ostræa *O. Leymerii*, is there, with *Inoceramus concentricus*, of whose Upper Greensand as well as Gault horizon Mr. Bose was not acquainted. *Cardium altum*, Forbes, is an Utátur shell, but it occurs in the Marl above the Nodular limestone also. *Inoceramus Coquandianus*, d'Orb., is the only Gault form. Three other species which will require more than simple rough determination before their presence is credited are said to be Neocomian.

All the reliable evidence is in favour of the Nodular limestone being above the Gault and belonging to the Upper Greensand horizon.

Conclusions.—The same species of Echinoidea are common in the three divisions of the Cretaceous series in the Lower Narbadá Valley, the sandstone being admitted by Mr. Bose to be of doubtful age is not included in this statement. The species thus persistent and four others which have a more limited vertical distribution are found in strata above the Gault and below the Senonian in Palestine and Europe. The three divisions of the Cretaceous series are conformable in their stratification. According to the elementary laws of Geology, strata which have species in common and are conformable were deposited during the continuance of one aspect of nature and belong therefore to a geological age, and not to more than one.

The Nodular and Marly and Coralline limestones are, therefore, deposits which accumulated during the Cenomanian age, that term being in a general sense the same as the Upper Greensand.

Description of and remarks on the Species.

1. Cidaris Namadicus, sp. nov. Figs. 1-3.

The test is large, high, with the equatorial diameter greater than the polar. Ambulacra narrow, wavy, with deep and wide poriferous zones and a projecting, flat-topped interporiferous area furnished with four close vertical rows of distinct

flattish granules. Pores, elliptical separated by a slight ridge and therefore non-conjugate, pairs numerous, close, separated by a narrow costa with a delicate linear ridge as the ornament. Twenty-five pairs of pores opposite the scrobicule of the largest interradial primary tubercle. Interradia wide, with a well marked median area, becoming deep at the junction of the median and lateral sutures; eight or nine primary tubercles in vertical series in each. Primaries with projecting but somewhat depressed perforated mamelons, rather tall, sloping, wide bosses, without crenulation, sunken externally, either circular in outline or slightly elliptical; scrobicular margin as a raised ring of large secondaries rather wide apart and having a broad flat base on which is placed an irregularly-shaped boss with a small mamelon; smaller secondary tubercles or very large granules, placed between the larger secondaries and slightly external to them. Scrobicular rings (abactinally) separate, with some slope beyond them, but close together or running one into the other nearer the ambitus and actinally; scrobicules always distinct. Slope beyond the scrobicules covered with large, irregularly placed, warty granules, rather flat, close, varying in size and with a few small ones near the sutural lines. The scrobicular rings come close to the poriferous zones, without any granular area.

Height, 45 mm.	Equatorial diameter, 50 mm.
" 42 "	" 60 "
" 35 "	" 40 "
" 30 "	" 38 "

Distribution.—Coralline Limestone Bowárla, Kherwan.
" " Chirákhán.
Argillaceous limestone, Chirákhán.

Description of the figures.–1. Part of a test, natural size.
2. Part of an ambulacrum, magnified.
3. A coronal plate with the primary tubercle, magnified.

This is a very fine species and may be known, at once, by the size of the high test, the wavy ambulacra with four rows of granules, the ridge-like linear ornament of the costæ, the close and huge scrobicular rings, the deeply seated median sutures and the large coarse irregular granulation of the slopes. It is unlike any European cretaceous form, but has some affinities with *Cidaris Cenomanensis*, Cott., but this has fewer primaries, wider slopes beyond the scrobicules and a delicate granulation.

2. Orthopsis indicus sp. nov. Figs. 4—8.

Test small, depressed, broader than high, flattish actinally, tumid at the ambitus, slightly convex abactinally. Ambitus circular. Apical system with five unequal, largely perforated basals which extend beyond the radials. Periproctal edge slightly raised. Radial plates small, narrow and unequal, and two or three enter the periproctal ring but no more. Periproct slightly and unequally ovoid, with its greatest diameter obliquely from radial plate II to basal 4. A few large granules are on the basals. Ambulacra narrow, breadth to that of interradia, 1 : 2·5. Pairs of pores in straight, simple series, numerous, close, often oblique; pores large, peripodia low with a median knob-like ridge. Plates–primaries alone, near the apex; low and broad compound plates near the ambitus, composed of three low primaries united by straight sutures. (Fig. 6*a*.)

Nearer the apex a low simple primary, carrying from one to three granules, separates the primary tubercle-bearing compound plates, which are composed there of two united primaries (Fig. 6*b*.). Primary tubercles of the ambulacra very small, numerous, perforate, increasing in size from the apex to the peristome, in two vertical rows, placed close to the pairs of pores. Granules few and mostly between consecutive primaries. Small secondary tubercles near the ambitus in the median area.

Interradia broad, with rather high coronal plates; with two principal vertical rows of primary tubercles, less numerous than in the ambulacra, larger than those of the ambulacra but otherwise similar, these extend from peristome to apex and are close to the middle of the plates near the ambitus. Near the apex the rows approach the poriferous zones. A second row of smaller primaries is on the ambulacral side of the rows just mentioned and the tubercles are close to the poriferous zones; these two rows, in each interradium, do not reach much above the ambitus. Two other vertical rows of primary tubercles are close to the median suture and they are as large as the others and reach to the ambitus. Thus there are four vertical rows of primaries and two reach the apex in each interradium. A few large granules are upon the plates and are distant.

Height, 10 mm., breadth 19 mm. Distribution:—Argillaceous limestone.

Figure 4, the test, natural size.
- „ 5, part of the apical system, magnified.
- „ 6, part of an ambulacrum, magnified.
- „ 7, coronal plate near the ambitus, magnified.
- „ 8, a coronal plate near the apex, magnified.

There is only one specimen of this interesting species in the collection, and the two other forms which were associated with it belong to the species next to be noticed.

Stoliczka described and figured *Orthopsis similis*, Stol., from the Arriálur group of the Cretaceous of Southern India (Pal. Ind., Cret. Faun. S. India, Vol. IV. page 116, pl. VII. 1873), and the new species is closely allied. The differences in the construction of the ambulacra can be appreciated by examining Stoliczka's fig. *2 d* and that which refers to the ambulacra of the new species (our fig. 6). There is not that difference in the size of the tubercles of the rows of the interradia which is seen in *O. similis*, to be observed in *O. Indicus*, and the median rows extend much nearer the apex in *O. similis* than in *O. Indicus*.

The whole of the radial plates do not enter the periproctal ring in *O. Indicus*, although they all do so in *O. similis*. The shape of the tests differs, and apparently the relative number of coronal interradial and ambulacral plates is not the same in the two forms. Finally the ornamentation of the Bág species is much more delicate than that of the other form. The most important distinctions relate to the radial plates and the construction of the ambulacral plates.

3. Cyphosoma Cenomanense, Cott., 1859: Ech. de la Sarthe, p. 150, pl. XXVI, figs. 13-16.

There are several specimens of this Echinoderm and most of them were collected by Captain Keatinge and are on tablets in the Calcutta Museum, but Mr. Blanford and Mr. Bose collected some others.

Distribution.—Coralline limestone, Bowárla, Kherwan, and S. of Raherda. Mr. Blanford collected near Dussai 15 miles W. of Mandoo. Captain Keatinge's specimens came from the Argillaceous limestone.

The resemblance of the specimens from the Bág series to the type, which has been illustrated by Cotteau with his usual care, is in some instances exact and in the others there is slight and unimportant variation. The numerous vertical rows of primary tubercles at and below the ambitus, six in each interradium, and the bare median space abactinally, with slight sutural markings, readily distinguish the species. In one specimen the construction of the ambulacral plates can be seen, and in the compound plates forming the greater part of the areas there are either four or five components which are arranged in the manner usual to Cyphosoma. (Duncan, Quar. Jour. Geol. Soc., 1885, page 449, fig. 23.) The aboral component is a large primary with the adoral suture curved with the convexity adorally directed. The next plate is a demi, and is shut out from the rest of the geometrically formed compound plate beyond the primary tubercle towards the median suture. The third plate is also a demi-plate; but the fourth is a low plate near the peripodium and expands towards the median line, the greater part of the tubercle being upon it and a considerable portion of the median suture being comprised in it. The next or lowest plate is a primary with the aboral suture convex aborally, or the reverse of what is seen in the upper primary plate.

4. Salenia Fraasi, Cotteau, 1885: Ech. nouv. ou peu connus, ser. 2, fas. 4 (Bull. Soc. Zool. de France) p. 59. Pl. VIII, figs. 1-5.

Syn. *Salenia petalifera*, Fraas (non Agassiz): Aus dem Orient: Geol. Beobacht. am Lebanon, 1878, p. 31.

There are three specimens of this interesting species in the collection made by Captain Keatinge, in the Indian Museum at Calcutta, and it is certainly somewhat remarkable that they should have escaped Mr. Bose's notice in dealing with the palæontology of the region which he surveyed. One of the specimens is so well preserved that the specific characters can be determined readily. The narrow ambulacra with the two close vertical rows of primaries, and the arrangement of the interradial primaries, and secondaries, assimilate the form with *Salenia scutigera*, Agassiz, and the nature of the ornamentation of the apical system places it within Cotteau's Lebanon species which he very properly states is closely allied to *S. scutigera*. *Salenia scutigera* is found on the same horizon as *Salenia Fraasi* in the Lebanon. The locality of *Salenia Fraasi* is in the Argillaceous limestone Chirákhán.

Salenia Arcotensis, Stol., is unfortunately a young specimen and yet the alliance to *Salenia Fraasi* is evident, for both have the close vertical rows of primaries in the ambulacra; but the species are distinct.

5 Echinobrissus Goybeti, Cotteau, 1885, *op. cit.*, page 60, Pl. VIII, figs. 6-10.

A large form of this well marked Echinobrissus is in the Chirákhán Marl and the details of the ambulacra enable it to be associated with the species described from the Lebanon Cenomanian by Cotteau. The very distinctly petaloid nature of

the ambulacral poriferous zones is characteristic, and the pairs of pores approach and nearly close the ambulacra above the ambitus. This is exceptional and is seen in the Bág specimen. The Bág form is larger than the type, but it has the same relative measurements. There are two specimens which were collected by Mr. Bose, and he considered them to belong to *Echinobrissus subquadratus*. This species was wrongly named by me. There is no doubt that the proper specific name is that given by Cotteau, and it must be admitted that the specimen wrongly determined was in such an indifferent condition, in every thing except its shape, that it should not have been named at all. Locality, Chirákhán Marl and Lebanon Cenomanian.

6. Nucleolites similis, d'Orb: Pal. Franc., Echinod.; see also Cotteau et Triger, Ech. de la Sarthe, p. 188; Desor, Synopsis, 1858, p. 259.

Two indifferent specimens of this form were collected by Mr. Bose from the Coralline limestone. They show the specific characters and also the doubtful generic character of the large round non-conjugate pores. *Nucleolites* is but a sub-genus of *Echinobrissus*, for the conjugation of the pores of a pair is of no physiological importance.

The European localities of the species are in the Chalk marl, and the Indian are the Argillaceous limestone and the Coralline limestone of the Bág area.

7. Hemiaster Cenomanensis, Cotteau, 1856: Ech. de la Sarthe, p. 210, pl. XXXIV, figs. 7 and 8.

Great numbers of specimens of different sizes and ages of this well marked species from the French Cenomanian have been collected from all the marine Cretaceous beds of the Lower Narbadá Valley. The form was found in the collection of the Geological Society, and it was stated in the description made in 1865 that the sole difference between the Indian specimen and the type was the comparative narrowness of the interporiferous areas of the ambulacra in relation to the breadth of the poriferous zones. The specimens collected by Mr. Blanford, and Mr. Bose added to those in the Indian Museum on tablets, enable the whole scope of variation of the species to be ascertained. The relative dimensions of the area and zones may be seen to be that of the type in many specimens and to vary in others. That character is therefore of doubtful specific value; but the length of the postero-lateral ambulacra and their shape offer some difficulties in comparing with exactitude the European and the Asiatic forms. The postero-lateral ambulacra appear longer and narrower in the Indian specimens than in the type, but when the number of pairs of pores delineated by Cotteau is counted, it will be found that there is hardly any or no difference between them in the posterior ambulacra of the two types. But the outward bowing of the postero-lateral ambulacra of the French form gives the appearance of a greater relative shortness in reference to the antero-lateral ambulacra than is warranted.

The sole distinction between the forms is, that in the Indian specimens the postero-lateral ambulacra are slightly narrower than in the type, and that is varietal. The essential characters are all present, namely, the large size, the high apex, the precipitous posterior truncation, the broad and deep anterior groove notching

the anterior margin decidedly and the slightly flexuous antero-lateral ambulacra. The fasciole is broad and resembles that of the type.

Hemiaster Cenomanensis, Cott., has been found in the Coralline limestone, Bowárla, Kherwan, and other localities; in the Marl at Chirákhán and in the Nodular white limestone at south of Raherda, on the Uri, and Jogardi, 6 miles southwest of Bág. Mr. Blanford collected numbers from near Dussai, 15 miles west of Mandoo and in the Coralline limestone, Chirákhán.

8. Hemiaster similis, d'Orb, 1854. Pal. Franc., terr. cret., t. VI, p. 229, and Cotteau et Triger Ech. de la Sarthe, p. 212, pl. XXXV.

Thi[illegible]s was noticed as a variety, in the collection of the Geological Society in 186[illegible] great number of specimens have been collected since from each of the thr[illegible] of beds belonging to the Cretaceous of the Lower Narbadá Valley. There is [illegible]ubt that there is much variation amongst the specimens, and indeed I was disp[illegible]at first to separate one or two in a closely allied species; but on placing the specimens together in series, it was found that these particular forms were linked on to others, and that the really important specific characters of *Hemiaster similis* are found throughout. There is no doubt that the tendency of the variation is towards *Hemiaster nucleus*, Desor, 1847, of the Turonian. The plump shape of the test, the shallow anterior groove not notching the anterior margin, the short postero-lateral ambulacra and the close broad fasciole are present in the forms, and those are the important characters of the species. It is interesting to find more specimens of this Upper Cenomanian species in the Nodular limestone than of the other Hemiaster.

DESCRIPTION OF THE PLATE.

Fig. 1. Ci[illegible]s namadicus, sp. nov., natural size.
„ 2. „ „ part of an ambulacrum magnified.
„ 3. „ „ A coronal plate with a primary tubercle magnified.
„ 4. [illegible]opsis indicus, sp. nov., natural size.
„ 5. „ „ part of the apical system.
„ 6. „ „ part of an ambulacrum, magnified.
„ 7. „ „ A coronal plate near the ambitus, magnified.
„ 8. „ „ A coronal plate near the apex, magnified.

Fie[redacted]: No. 5—*to accompany a* Geological Sketch Map *of* Afghanis-[redacted]*d* North-Eastern Khorassan, *by* C. L. GRIESBACH, C.I.E., [redacted]*cal Survey of India.*

Physical characters.

[redacted]án is a land of high mountain ranges and two great areas of steppes; about three-fourths of its drainage passes to the Indus and to the inland basin of the Helmund, and only the northern portion, not much more than one-fourth of the entire area, belongs to the Aralo-Caspian depression.

Ranges.

By far the most important of all the ranges of Afghanistán are the Hindu Kúsh and Koh-i-Bába chains of mountains, which connectedly form the watershed of Afghanistán. The Hindu Kúsh has a north-east to south-west direction, and divides the drainage of the Oxus river from that of Chitral, Kafiristán, and Kabul; the range joins the Koh-i-Bába near the Shibar pass south-east of Bamián, and thence pursues a more or less east and west direction. The western prolongation of this chain forms the watershed between the Seistán drainage and the Hari Rúd (Tejénd) and is known under various local names. In Khorassan the same system of ranges continues, but [redacted]-west strike.

The range or system of ranges which comes n[redacted]rtance after the great Central Afghan watershed is the system of parallel ranges which forms more or less the political boundary between India and Afghanistán, namely, the chains amongst which the central portion is known on our maps as the Sulimán range, named after the highest point in the range—the Takht-i-Sulimán. Geographically all the parallel ranges, from the Afridi hills near Peshawar to the Búgti hills south-west of Dera Ghazi Khán, form one connected system of mountains.

The entire intervening area between the Sulimán mountains and the great Afghan watershed is formed by a series of high chains with wide troughs between. They start in the Kabul district and gradually diverge as they are followed south-westwards to the Persian frontier.

The structure and origin of these ranges is very simple. They are formed by a series of anticlinals, often compressed into a narrow belt with steep folds, at other points forming wide arches, and in some cases even plateaux.

Rivers.

The drainage of Afghanistán belongs to three separate areas. The Indus basin receives the drainage which flows from the Hindu Kúsh, Kafiristán, the Sulimán range, and of the ground west of it. The streams which rise in the Búgti hills and part of Biluchistán also run into the Indus basin.

The Ghilzai country and the southern Hazarajat send forth streams, which drain into the inland basin of Seistán; the Helmund is the largest and most important of these rivers.

The third drainage area is that of the Aralo-Caspian basin, to which the Oxus, the Balkh-áb, the Murgháb, and the Hari Rúd (Tejénd) belong. Of these consider-

able rivers only the Oxus reaches a defined lake basin, namely, the Aral sea; the remainder loose themselves in the sands and swamps of the Central Asian steppes.

Nearly all the rivers of Afghanistán have had the same history. They date back to late miocene times, since which period they have scooped out deep gorges and valleys whilst the country was gradually being laid into great anticlinal folds. Consequently they have nearly all of them formed fine examples of transverse valleys, which belong to the most characteristic features of Persian or Afghan landscapes.

Work done in Afghanistán.

As will be seen from the annexed map, the greater part of Afghanistán is geologically still a *terra incognita*. All the mountainous country from the Sulimán range to the Hazarajat including the Zhob valley, has never been visited by a geologist. The Upper Hari Rúd, the Firozkohi country, and a large portion of the Northern Hazarajat are unknown to us geologically. So is the Taimuni country and the valleys which descend from the Siah Koh. During the second Afghan campaign, 1880, I reconnoitred the route from our Indian frontier to the Helmund, including the country south-west of Quetta. Afterwards (in 1883) I had the good fortune to accompany the Takht-i-Sulimán expedition under General T. G. Kennedy, C.B., and so was able to visit the highest part of the Sulimán range, which I found to be a stratigraphical continuation of the hills west of Dera Ghazi Khan, which have been described by Dr. W. T. Blanford. Later on, in 1884, 1885, and 1886, I was attached to the Afghan Boundary Commission, and examined the entire west and northern frontier of Afghanistán, together with Eastern Khorassan and the greater part of Afghan Turkistán, and was able to reconnoitre one section from the Hindu Kúsh to India. The outlines of the geological results thus arrived at are laid down in my published " Field-notes " in the Records. In the following pages I intend to summarize these results shortly. The geological literature relating to Afghanistán is extremely limited. I have already given lists of previous authors on matters connected with the geology of Afghanistán in former papers;[1] it would be superfluous to again review this literature, as I shall have to do that when fully discussing the geology of Afghanistán in my forthcoming report.

The annexed table will show the formations met with in the examined area of Afghanistán and Khorassan and their distribution. Since the publication of my " Field-notes " in the Records, some of the leading fossils of several formations have been examined by Dr. F. Noetling, and in consequence the " *Red grits* " had to be separated from the jurassics, with the uppermost portion of which I had previously identified them, and they are now included in the neocomian.

[1] Mem. Geol. Surv., Vol. XVIII; Records Geol. Surv., Vol. XVII, pt. 4, p. 177; *ib.* Vol. XX, pt. 1, p. 18.

Groups.	Khorassan.	Herat Province.	Turkistán and South-western Badakhshán.	Section from Sibi to Kandahar.	Kabul.	Sulimán range.
Recent	Blown sand in North-eastern Khorassan; alluvial deposits; salt-pans.	Blown sand of Herat valley and Northern Badghis; alluvial deposits.	Blown sand of the Chúll and the Oxus valley; alluvial deposits; glacial remains (old moraines of the Tirband and Hindu Kúsh).	Blown sand of the Registán, Lower Helmund, &c. Alluvial deposits.	Reg-i-Rowán near Kabul; alluvial deposits, &c.	Recent fans of rivers; alluvial deposits, &c.
Upper Pliocene	Loess deposit of lower Jam valley, Nishapúr plain, &c.	Loess of Badghis with beds of sandstone and conglomerates	Upper pliocene and older loess of the Chúll; upper freshwater series of Mathár and Bamián. Gravel beds of the upper Surkh-Rúdin the south-western corner of Badakhshán.	Gravel beds of the Helmund; breccia deposit of the valleys, laterite of Kandahar.	Gravel terraces of the Ghorband valley of Kabul, the Lataband, &c., &c.	Indus gravel beds on the east slope of Sulimán range.
Lower Pliocene	?	Upper sandstone and plant beds of the Herat valley (Tirpúl beds), north of Shabash, Tirpúl, &c. Red and white clays with freshwater shells of Sakhra in the Murgháb valley.	Lower pliocene plant-beds of Mathár and Bamián. Sandstone of Tashkhurghan, &c.	Sandstone and gravels with bright coloured clays of Pishin valley, Quetta neighbourhood and Nari gorge.	Sandstone (upper Siwaliks) of Kabul river valley near Candamák, &c.	Sandstone, clays, and conglomerates of upper Siwaliks, fringing the east slope of the Sulimán range.
Upper Miocene	?	Lower plant-beds of Tirpúl with gypsum	Estuarine beds of Mathár	?	?	Sandstones, clays, marls, &c. (Blanford, lower Siwaliks). Nari sandstone, &c. (Blanford).
Lower Miocene	Sandstone with Ostrea multicostata, Desh., near Khaf.	Red clays and grits with Ostrea multicostata, Desh., of Badghis (Nimak-sar and at Khwaja Kallandar).	Lower miocene (Gasteropod beds) of Mathár (Marine) Ostrea multicostata beds near Tashkhurghan and at Kilif on the Oxus	?	?	
Eocene	Nummulitic limestone with Rhyolites, between Nishapúr and Mádan.	?	Eocene of Bajgáh, Bamian, &c.	Khojak beds	?	Olive clays, shales, sandstones, &c., with nummulitic limestone.
Upper Cretaceous	White chalk of Kelát-i-Nadri and Zorabad. Inoceramus beds of Zorabad Exogyra limestone, Takht-i-Gaúzak near Púl-i-Khatun, Kelat-i-Nadri, &c.	White chalk with fossils, south of Kala Nao. Exogyra limestone of Darband, south of Balá Murgháb. / White limestone with Inoceramus cripsi at Zulfikár and Ardewán pass. / Hippuritic limestone of the Doshakh range and Paira. Coral limestone of the Doshakh peak.	Upper cretaceous of Turkistán with Hippurites, &c.	Hippuritic limestone of Kandahar, Shah-Maksud range, &c.	Upper cretaceous limestone of the Lataband range, &c. Afridi hills.	Hard whitish sandstone grit dark grey limestone passing downwards into dark limestone shales.
Middle Cretaceous	Trigonia-beds and shell limestone of the Takht-i-Gaúzák; white plant-sandstone of Kelat-i-Nadri.	White sandstone and grits with Ostrea sp., and plant-remains of the Kashka Kotal. Shell limestone of the Band-i-Bába. / White marls, and clay-shales with marine fossils of Zulfikár.	Lower cretaceous (Astar-ab, upper Almar stream).	Lower cretaceous breccia bed and conglomerate.	?	
Neocomian	Red grits of Kat-i-Shamshir (south-east of Máshhád); Madan west of Nishapúr; Firaiman south-east of Máshhád; Yaktán range.	Red grits with volcanic breccia of the Barkhut range (Chasma Sabz pass, Robat-i-Surkh pass, Ardewán pass, Kúrúkh, Davendar range, &c.	Red grits of the Tirband range, Astar-ab, Doab north of the Kara Kotál, Khorak-i-Bala, south of Tashkhurghan, &c., &c.	?	Red grits of the Lataband range., &c.	
Jurassic, &c.	Black shales with fragments of plants of Zorabad; Garmáb (Kat-i-Shamshir range); west of Takht-i-Gaúzák. Limestone and shales with marine fossils of the Gaúkharchang pass (Burj-i-Kalij Khán).	Black shales of Kurukh valley, Robat-i-Surkh pass. Brachiopod limestone of Jaoza	Black shales of Khorak-i-Bala, Doab, &c., north of the Kara Koh. Plant beds of Shisha Alang, &c. Brachiopod limestone of Shisha Alang.	? ?		Dark shales of the hills west of the Takht-i-Sulimán ?
Rhaetic Trias and Permian ?	? Green shales of Yaktán range and Dehrúd pass. ?	Brachiopod limestone Kholi Biaz, east of Herat Plant shales and sandstone. Green shales of Kholi Biaz. Green plant shales with thin coal-seems of Kholi Biaz.	Rhaetic of Shisha Alang. Halobia lommeli group of Chahil, &c. Lower trias and anthracite group of Saighan.	? ? ?	? Altered rock with graphitic Seams of the Hindu Kush and the Gorband valley.	
Carboniferous	Carboniferous Productus-limestone of the Yaktán range, Dehrúd pass, &c.	Carboniferous Productus-limestone of Robat-i-Pai, Doshakh range, and Kholi Biaz.	Carboniferous limestone of Ak Robat and near Chahardar.	?	Altered limestone of the Gorband valley; Lithodendron limestone of the Safed Koh; hills near Khaiber mouth west of Peshawar.	
Sub-carboniferous	Dehrúd pass	?	?	?		

General geological features.

It will be seen that the older rocks (palæozoic and mesozoic) are met with chiefly along the great Central Asian watershed, the main axis of Afghanistán. Strips of these rocks occur also at a few localities north of the main axis, and some doubtful and unfossiliferous rock groups in the Kabul district may possibly also be of older date than cretaceous. The rest of Afghanistán is covered with a thick skin of cretaceous rocks, the upper beds of which are often found to rest unconformably on the underlying older mesozoic strata. Large areas on the western and northern margin of Afghanistán are covered by tertiary strata.

Structural outlines. Afghanistán.

The main axis itself with the country north of it is part of a regular system of flexures,[1] closely compressed near the main axis, but gradually increasing in width towards the north until they become gently undulating waves and widely spread flats towards the centre of the Turkomanian area.

A similar feature is observable on the Indian side of the great watershed. The spurs which I crossed between Quetta and Kandahar not less than the ranges lying between the Hindu Kúsh and Peshawar together with the Sulimán range are nothing but portions of flexures, and it may be inferred therefore that all the highlands of the Hazarajat and Ghazni down to our frontier show much the same structure as the ranges north of the Afghan watershed.

Central Asia and Persia.

All the formations met with in Afghanistán are also found spread over the greater part of Central Asia. The main axis of Persia which forms geographically a continuation of the Afghan watershed, resembles the latter also in its geological structure. The palæozoic and older mesozoic rocks are only met with in strips near the main axis and are elsewhere hidden by cretaceous and tertiary formations. The latter cover by far the greatest area in Turkomania and Russian Turkistán, Bokhara, &c., and only along the eroded base of synclinals older rocks appear. (Mushketoff's Turkistán.)

Carboniferous and older rocks.

Beds with true carboniferous forms have been found from the Araxes in Armenia to Central Afghanistán. They form narrow strips at the base of the older mesozoics, and as such they have been traced in a more or less uninterrupted zone along the Central Asian watershed. In some places in Persia they overlie some strata which have yielded fossils of rather devonian than carboniferous aspect, and it is possible that perhaps the entire palæozoic series will be found to exist. The same rocks extend into Russian Turkistán, where they crop up from beneath the covering of mesozoic (chiefly cretaceous) formations. Limestones and shales which contain apparently the same fauna have long been known to exist in Kashmir[2] and the Himalayas, and it seems therefore probable that all these carboniferous "islands" belong to the same widely spread formation and have been deposited in the same continuous sea. The dark limestone with *Productus* of Robat-i-Pai near Herat is both palæontologically and lithologically identically the same as the *Productus*-limestone of Spiti and the Central Himalayas generally.

[1] Records, Vol. XIX, p. 236.

[2] See Lydekker's Kashmir: Mem. Geol. Surv. India, Vol. XXII.

I have myself traced it from the Binalud range in Khorassan through the Yaktán hills and the Doshakh range to the slopes of the Davendar east of Herat, and met with it again near Saighán north of Bamián. The dark limestones of the Hindu Kúsh[1] and Kabul (Jagdalak) I have provisionally identified with the carboniferous, and it appears likely that the latter is only an outlier of the Attock slate series, in which possibly some of the older palæozoics may be found.

It is remarkable that nothing older than upper mesozoic formations have been discovered in Southern Afghanistán and the Sulimán range.

Plant-bearing series. Permo-trias and jurassic.

Above the carboniferous group and conformable to it an extensive and continuous series of strata occurs not only in Persia and Armenia where they were noticed long ago, but also in Afghanistán. They form a more or less continuous belt of strata, closely connected with the underlying carboniferous group, and distributed along the entire distance from the Araxes in Armenia to the Hindu Kúsh, therefore following more or less the line of the great Central Asian watershed.

Whereas the carboniferous group consists of entirely marine deposits, the overlying strata bear the character of having been precipitated close to a coast-line; marine beds alternate with purely freshwater ones or with littoral formations containing plant-remains and coal-seams.

The thickness of the group varies very largely from a few hundred feet (Herat) to many thousands, as for instance in the Saighán section.

The fossil contents of the series will have to be worked out in detail hereafter; at present so much is certain that it rests on beds with a carboniferous fauna and is conformably overlaid by neocomian strata and therefore represents the permian, trias and jurassic formations.

Of these the last have furnished many fossil remains, both marine and terrestrial (plants). The triassic group is well characterised throughout by both plant and marine remains; the oldest fossil identified being a *Halobia* species, which I found near Chahil north-west of Saighán in Afghan Turkistán. The lowest trias is at that place hidden by upper cretaceous deposits. Further southwards the series crops out again from under its mantle of cretaceous limestone, and I found greenish grey shales (altered by granite intrusions) with anthracitic seams and a conglomerate with greenish matrix which group of strata rests conformably on the carboniferous limestone and even partially alternates with the latter.[2] I believe this formation to be the same as the carbonaceous shales and conglomerates of the Kholi Biaz[3] near Herat, and also to be identical with the hard greenish sandstone and shales which rest conformably on the carboniferous near the Doshakh peak (Herat valley) and near Gulistan and Jaghárk south-west of Mashhad in Khorassan.

It appears probable that the series between the carboniferous limestone of Bamián and the *Halobia* beds of Chahil is in Afghan Turkistán continuous below the unconformable cover of upper cretaceous limestone, and that therefore

[1] Records, Vol. XIX, pt. 4, p. 240, and Vol. XX, pt. 1, p. 22.
[2] Records, Vol. XIX, pt. 4, p. 240.
[3] Records, Vol. XIX, pt. 1, p. 54.

the upper permian and lower trias is hidden. I expect that these groups will be discovered in the "green shales" and the strata above them which play such an important rôle in the hill ranges of Northern Persia. They may also be found in the deeply eroded river valleys of the upper Balkh-áb and the highlands of the upper Hari Rúd, which I could not visit.

The same formation of littoral deposits is found in many localities in Russian Turkistán, where they also contain coal-seams as in Afghanistán and Persia. The formation bears entirely the character of being deposited along a coast, the outline of which nearly corresponds with the present direction of the hill ranges which begin in Armenia, extend through Northern Persia (the Elburz), through Khorassan, and finally divide Afghanistán into two separate drainage areas. The sea in which this formation was deposited must have been a shallow one, as is shown by the lithological character of the deposits. Numerous rivers seem to have carried not only eroded mineral material but also a large quantity of vegetable matter out to sea, for plant-remains are mingled with marine shells and carbonaceous beds and coal-seams alternate with shell limestone. In some places, probably in sheltered bays, great thicknesses of such deposits were laid down and large coal-seams have been formed, as for instance north of Saighán in Afghan Turkistán (Shisha Alang, Chahil, &c. [1])

Sufficient data are now available to show that this littoral development of the permo-triassic series is uniformly the same over a great part of the Elburz ranges of Northern Persia, in Khorassan, Northern Afghanistán, and over a large portion of Russian Turkistán. This area is flanked on each side by a succession of permo-triassic strata of purely pelagic character. On the Araxes in Armenia [2] Abich has found beds containing marine forms which also occur at the base of the triassic group in the Himalayas. These Armenian strata may be represented in Persia and Afghanistán by the green shales and conglomerates (Saighán, &c.) which may be regarded as forming a passage from the palæozoic *Productus*-beds into the lower trias.

In the Central Himalayas I found immediately resting on the carboniferous *Productus* group a succession of beds, the bottom one of which contains forms also met with in the Araxes passage beds. In the Himalayas the entire series of the permo-trias is of marine origin.

The Central Asian facies of the permo-trias bears a strong resemblance to the Gondwana series of India, not only lithologically but also palæontologically.

The general lithological characteristics of the Gondwana series of India are that of a great thickness of sandstones and shales (with coal-seams) containing plant-remains, which begin at their base with a generally greenish coloured conglomerate, sandstone, and shales, and which ends with a great thickness of coarse-grained sandstone and grits (Mahadevas &c.).

The permo-trias and jurassic series of Central Asia is a succession of marine and littoral formations, which also begin at their base with a greenish conglomerate,

[1] Records, Vol. XIX, pt. 4, p. 243.
[2] H. von Abich: Geol. Forsch. in den Kaukas. Länd., Pt. 1, 1878.

sandstone, and shales, and ends with coarse sandstone and grits with volcanic ash beds (late jurassic and neocomian).

The middle of the series is well characterised by fossil remains, amongst which are typical triassic and jurassic marine forms, associated with plants which also occur in the middle Gondwanas (*Schizoneura*, &c.). Similarly both in the Gondwanas of India and the permo-trias of Central Asia, coal-seams are chiefly developed in the middle of the series.

But unlike the Gondwanas, the Central Asian series is correctly defined as regards its age; it is inclosed between carboniferous *Productus*-beds and neocomian strata. The lowest beds of the series are partially alternating with the carboniferous group, and the upper portion of the plant-series is passing gradually into the marine neocomian horizon. The ages of several of the middle and upper zones of the series are accurately fixed by their marine fossils. We have therefore an extensive series of strata, the lowest beds of which may be regarded as carboniferous and the uppermost as of upper jurassic and neocomian age, and of which only the permian and lower trias is destitute of determinable organic remains. It is interesting to notice that just these lowest beds, which are closely connected with and alternate with the carboniferous group, resemble lithologically the lowest Gondwanas or Talchirs in some important characters and like them contain impressions of *Vertebraria*-like forms.

From the clearly establised upper trias (*Halobia lommeli* horizon) to the neocomian, the succession of fossiliferous strata is continuous.

The upper plant-shales yielded middle and upper jurassic marine fossils; lithologically they resemble the Spiti shales of the Himalayas, and they alternate and pass into the "red grit" group, the upper portion of which is undoubtedly neocomian as is proved by their fossil contents.

Cretaceous group.

The cretaceous series forms wide-spread deposits in Afghanistán and indeed over a large area of Central Asia. A large portion of Afghan Turkistán with the hills (Tirband-i-Turkistán, Koh-i-Bába, &c.) is formed of cretaceous rocks. West and north-west the cretaceous group extends in strips through the Herat province into North-eastern Khorassan. And south of the great Afghan watershed and as far as the Indian frontier I believe cretaceous rocks will be found to form most of the ranges, which run in long lines, south and south-west from the Koh-i-Bába and the Kabul highlands.

I have found cretaceous rocks in great force in the section between the Hindu Kúsh and Peshawar, whilst the south-western extensions of the Central Afghan ranges —the spurs which extend to Kandahar, the Khojak range, and Quetta—are also composed of upper cretaceous rocks. So also is the principal chain of the Sulimán range, of which the Afridi hills near Peshawar form a northern continuation. In Khorassan and Northern Persia the cretaceous formation forms great ranges and plays an important part in the structure of the chains of mountains which skirt the northern frontier of Persia. In Central Asia the upper cretaceous covers a large area, and hides nearly all the older formations, which appear only in isolated patches, where the overlying cretaceous mantle has been denuded. In the sections of the central Himalayas and Kashmir the cretaceous formation is comparatively rare, but it is probable that further to the northwards and north-east great tracts of the Central

Tibetan ground is formed of cretaceous rocks. There is evidence[1] that cretaceous rocks are *in situ* in the neighbourhood of Lhassa.

Several horizons of the cretaceous group are represented in Central Asia. The most complete sections I met with in Khorassan where apparently all horizons from the neocomian (with marine fossils) to the upper cretaceous *Exogyra*-limestone are represented.

Further eastwards, in the Herat province and in Afghan Turkistán, the middle cretaceous seems altogether wanting in most of the sections, and in that case the upper cretaceous *Exogyra*-limestone rests unconformably on the jurassic or older groups of the plant-bearing series.

In Afghanistán and Central Asia tertiary formations form wide-spread deposits.

Tertiary system.

Along the southern, south-western, and partly the western boundaries Afghanistán is skirted by tertiary and sub-recent deposits, which form most of the deserts and great plains of the lower Helmund drainage. Tertiary deposits also fill the Herat valley and extend far into the valleys of Eastern Khorassan. Badghis, drained by the Hari Rúd, the Kushk and the Murgháb rivers, the Maimana province, and the greater part of Afghan Turkistán with the Oxus valley, form part of the enormous Aralo-Caspian basin, which is for the most part filled with tertiary and later deposits. Only along the southern edge of the Badghis and Turkistán tertiary area older beds of this system crop up, namely, eocene and miocene marine strata. Small patches of such are seen inclosed in synclinal basins high up in the highlands of Saighán and Bamián, and a belt of older tertiaries also crops up on the Oxus near Kilif and Khamiáb.

The deposits on the north slope of the great Afghan watershed differ in many respects from those which form a fringe to the cretaceous Sulimán range and compose most of the Búgti and Marri hills east of Quetta.

In the Herat valley, Eastern Khorassan and the steppes of Badghis, Maimana and Turkistán the great divisions of the tertiary series are:—

		6. Blown sands and recent alluvium.
Upper	Pliocene	5. Loess deposits and old fans.
Lower		4. Freshwater deposits with plants and land shells.
Upper	Miocene	3. Estuarine deposits.
Lower		2. Marine miocene beds.
		1. Eocene.

The eocene formation has only been proved to occur in one locality, namely,

Eocene.

near Nishapur, in Khorassan, where nummulitic limestone occurs. In Badghis and Turkistán the upper cretaceous limestones are overlaid by marly limestones in thinner beds and sandstone which are again overlaid by fossiliferous miocene strata. This intermediate formation, which is of considerable thickness, I believe to represent the eocene horizon.

The miocene formation, both lower and upper, is of wide-spread extent

Miocene.

in Central Asia, and to it belong nearly all the salt and gypsum deposits, many of which are worked. I believe the Afghan miocene formations to be essentially the same as the gypsiferous series of Persia described by Loftus, Abich, Grewingk, &c., and which forms

[1] O. Feistmantel: Records Geol. Surv. India, Vol. X, p. 21.

such large deposits in Western and North-western Persia, Armenia, and the Caucasus.

North of the Afghan watershed, older tertiaries appear along the north slope of the Barkhút range (the Paropamisus of our old "Turkistán" maps), seem to fill the Murgháb (Ferozkohi) synclinal, and may be traced in patches north of the Koh-i-Bába (Mathár, Bamián). North of the anticlinals of the Tirband-i-Turkistán they crop up again in a long fringing line, resting conformably on the upper cretaceous limestone and strike east from Tashkhurghan. Due east of the latter locality, miocene strata (salt-bearing) appear at Khánabád in Badakhshán, where probably the two lines of tertiary synclinals join. The area east of Khánabád with the Hindu Kúsh and Kafiristán is chiefly composed of metamorphic rocks,[1] which may have formed part of a great crystalline massif. On the Oxus and beyond, in Bokhara, older tertiaries again crop up, and it appears that in Central Asia these rocks participate largely in the formation of the hill ranges.

How far the older (marine) strata of the tertiaries of Turkistán resemble the eocene and miocene formations of Sind and Biluchistán will have to be determined hereafter, when the fossil contents of both have been compared.

Tertiaries south of the watershed.

South of the great Afghan watershed older tertiary deposits are found in the neighbourhood of Kohat, whence they strike southward, fringing our frontier and the Sulimán range. Probably the large triangular area between the Sulimán range, the Búgti hills, and the line which connects the Pishin valley with Kohat will be found mainly to be formed by tertiary deposits. Upper tertiary formations cover a large area in Southern Afghanistán and the neighbouring ground. The frontier belt of Afghanistán and Biluchistán with many of the wider valleys inside the hills are made up of later tertiaries.

Changes during and after miocene times.

During the miocene period began the changes in the distribution of land and sea which continued during later tertiary times and are still going on. The miocene sea gradually retreated from the western shores of the Afghanistán (Badakhshán, Kafiristán massif) continent, and large estuaries began to form along the coast-lines in which the latter miocene deposits were laid down. Such is evidenced by the Bamián and Mathár, the Tashkhurghan and many other sections in Central Asia.

The change of conditions must have been very gradual, for there is no break in conformity visible between the drab clays and shales of the estuarine upper miocene and the densely bright coloured, red, and purple clays, sandstones and shales with conglomerate of the upper tertiaries, which is a purely fluviatile and lacustrine formation.

These conditions find their analogue in the Biluchistán sections, where the change from the miocene (Gaj) beds into the upper miocene (lower Manchhars) is equally gradual. The upper Manchhars (upper Siwaliks) of Sind and Biluchistán may be compared with the Turkistán freshwater pliocene. The lithological resemblance of the latter with the upper Manchhars of Sind or upper Siwaliks of the trans-Indus range is remarkable.

[1] Dr. Giles: in Ann. Rep., Records, Vol. XX, pt. 1, p. 9.

Changes continued to recent times.

The same changes, *i.e.*, the retreat of the miocene sea from the tertiary continent and finally its separation into several lake-basins (the Aralo-Caspian), continued long after the deposition of the estuarine strata along the margin of the Turkistán highlands.

Aerial formations. Loess.

With the change of outline of these lake-basins and the diminution of rainfall and consequent decrease in volume of the drainage flowing from the Afghan highlands, begin to appear aerial formations, which near the margin of the hills are seen to be intercalated between the fluviatile deposits of the upper tertiaries. In pliocene times already began the accumulations of vast deposits of loess, whose aerial origin is clearly shown in the scarps which every Turkistán river cuts through it in its northward flow.

The accumulation of loess is still going on over a large portion of Central Asia including Northern Afghanistán. The steppes owe their origin to the nature of the recent deposits of loess. Every one of the wider valleys of Eastern Khorassan and the Herat valley are partly filled with loess accumulations. The grass-covered downs (Chúll) of Badghis, Maimana, and Afghan Turkistán are nothing but widespread loess deposits.

In South-western Afghanistán the conditions are similar. There the gradually drying-up inland basin of the Helmund is under the influence of air-currents which deposit vast thicknesses of loess on both banks of the Helmund and in Seistán; they rest on stratified deposits of clay, sands and conglomerate, which are lithologically identical with the Chúll deposits of Turkistán.

For the description of the Biluchistán ranges,[1] the Búgti hills,[2] and the Sulimán range [3] I refer to the descriptions given in the publications of the Geological Survey of India.

Igneous rocks.

I found it impossible to separate the various intrusive igneous rocks on the small scale map which accompanies this paper. I believe the igneous rocks of Afghanistán and North-eastern Khorassan belong, broadly speaking, to four different epochs. They are :—

4.	Trachytes and rhyolites of Khorassan	Tertiary.
3.	Trap Syenitic granite	Eocene.
2.	Trap	Jurassic and neocomian.
1.	Trap and melaphyre	Permian.

1. The oldest igneous rock of Afghanistán I believe appears as interbedded trap and melaphyre in the lowest beds of the plant series, which I have correlated with the permian of the Araxes and the Himalayas and the Talchirs of India. They are well seen in the Herat sections and in the north-western extension of the Yaktán range of Khorassan.

2. Enormous outbursts of traps and porphyritic rocks appear as intrusive and partly interbedded masses in the red-grit group. They are particularly well seen

[1] W. T. Blanford: Mem. Vol. XX, pt. 2. C. L. Griesbach: Mem. Vol. XVIII.

[2] W. T. Blanford; Mem. Vol. XX, pt. 2.

[3] W. T. Blanford: Mem. Vol. XX, pt. 2. C. L. Griesbach: Records, Vol. XVII, pt. 4, p. 175.

in the Herat province; the Ardewán, Marbich, Band-i-Bába, and Zurmust passes lead over sections through these late jurassic traps. The upper beds of the red-grit group are almost entirely made up of fragments of igneous rocks and great thicknesses of ash-beds swell out the total of this group enormously.

3. Structurally the most important of the igneous rocks of Afghanistán are the syenitic granite and trap outbursts of post-cretaceous times. They form dykes and bosses in Khorassan and the Herat province (Davendar) and form most probably a continuous belt through Central Afghanistán. I met them again in great force in the Hindu Kúsh, which, with its parallel chains north and south, is nearly entirely composed of these rocks.

They are seen to penetrate the upper cretaceous limestone, which is then frequently converted into white marble near the contact.

I believe the outburst to date either from late cretaceous or eocene times.

To it belong the post-cretaceous syenites and traps of Kandahar and the desert south of the Helmund.

4. In Eastern Khorassan appear trachytes and rhyolites (north-west of Nishanúr) which have intruded between strata of nummulitic limestone and therefore can hardly be older than middle tertiary.

Summary. The following facts may again be summarized.

1. The carboniferous group shows great points of resemblance, both lithologically and palæontologically, over the entire distance from the Caucasus to the North-west Himalayas. It is a purely marine formation, and pelagic conditions seem to have prevailed in the Caspian region, Northern Persia, Afghanistán, and the Himalayan area.

2. At the close of the carboniferous period began a shallowing of the sea over the greater part of Central Asia, including Northern Persia and Afghanistán, which more or less continued to neocomian times, when the sea altogether retreated from large tracts of Central Asia, including Afghan Turkistán.

During that time littoral deposits were laid down along a coast line which seems to have agreed more or less with the present direction of the Central Asian watershed.

In the adjoining areas, of Asia Minor and the Himalaya, pelagic conditions continued.

3. In upper cretaceous times a great overlap of the sea began and extended to lower miocene times.

4. After the deposition of the lower miocene the sea began to retreat gradually from the coast-lines, not only in the Central Asian area, but also in Sind and Biluchistán, and estuarine and freshwater deposits were being laid down conformably on the marine miocene beds.

The retreat of the miocene seas was continued in late tertiary times and in fact the same changes are still proceeding at this moment. In place of the estuarine deposits huge accumulations of freshwater and aerial formations took place over the greater part of Central Asia, Persia, and our Sind frontier.

Notes on the Microscopic structure *of some specimens of the* Rájmahál *and* Deccan traps, *by* COLONEL C. A. MCMAHON., F.G.S.

(Received December 23, 1886.)

Igneous rocks of the Rájmahál group: Augite-Andesites.

1—434[1].—Amygdaloid. Motijharna.

This rock has been considerably decomposed by the percolation of water, and has been reduced to a condition that reminds me very much of the traps of Mandi and Darang, in the Himalayas. The matrix of the amygdaloid consists of a network of felspar prisms, starred about in a muddy-looking, and almost opaque, base of greenish-brown colour. In reflected light this is seen to be studded at regular intervals with fine fibres of magnetite which radiate in all directions. The slice is dappled here and there with an amorphous red product; remains of augite are also visible, but this mineral has been altered almost out of recognition.

All the felspar belongs to the triclinic system, and none of it appears in the form of porphyritic crystals

1—441.—Amygdaloid. Dubrajpur.

The matrix of this specimen is composed of triclinic felspar, augite, and magnetite. The felspar occurs both in porphyritic crystals, and in small but regular prisms. If the former were left out of consideration, the smaller felspars and the augite would be in about equal proportions to each other. The augite is in a granular condition; that is to say, it does not present crystallographic outlines.

A zeolite, varying from white to yellowish-red in colour, stops the amygdules, and invades the substance of the rock, forming very numerous *lacunæ*, with strongly marked marginal borders. The inner portions of many of the large felspars have also been replaced by this product of decomposition. With this exception the rock presents a fairly fresh appearance.

Among the felspar crystals, crosses formed by baveno twins are common; and whilst twinning on the albite plan is visible in nearly all the felspars, pericline macles are also to be seen here and there.

Augites occur in both these slices in somewhat large crystals as well as in smaller granules, and a few of them present rather good external shapes. Twinning is to be observed in some of them, but it is not at all common.

The augite and felspar appear, on the whole, to have crystallized simultaneously, but instances are not wanting to show that some individuals of both minerals crystallized in advance of others. Thus these slices present examples of twinned and well-formed augites, and groups of augites, imbedded in rather large felspars; and also of augites formed upon felspar prisms. In other cases the growth of the latter mineral has apparently been stunted by the formation of crystals of pyroxene by their side.

[1] The numbers given are those of the Geological Survey of India.

This feature, *viz.*, the simultaneous formation of augite and felspar, and the enclosure of augite by felspar, and of felspar by augite, was noted as a characteristic of the Bombay basalts in my paper on those lavas, see Records XVI, pp. 43, 46, and plates. I may further draw attention to the fact, in passing, that the inclusion of groups of well-formed augites in large felspars, noted above, shows conclusively that we must not jump to the conclusion that all large felspars porphyritically imbedded in a finer grained ground-mass necessarily belong to a different "generation," and had their birth considerably in advance of the smaller crystals of the ground-mass. The porphyritic and zoned felspars were doubtless formed before the small prisms of felspar; but the interval between them need not have been great in point of time, and the birth of both may have been the result of cooling when the lava began to consolidate after it had flowed from the mouth of the volcanic crater. At any rate, it is clear that some small crystals of augite were formed in the magma prior to the crystallization of the large felspars, and we may reasonably infer that the crystallization of the whole mass had begun when the porphyritic felspars were formed. This inference is also supported by a further fact observed in slice No. 436; namely, that there is a gradation from the felspars of largest to those of smallest size, and not an abrupt transition from large porphyritic felspars to small lath-shaped prisms.

In No. 436, magnetite is very abundant. The products of decomposition are, in No. 436, a greenish-brown; and in No. 440, a substance that is of greenish-brown colour in some places, and yellowish-red in others. This cannot be traced directly, or indirectly, to the alteration of augite; on the contrary it fills the rôle of a glassy base, and possibly represents the uncrystallized residuum. The pyroxene is very fresh, but occasionally inner portions of the large felspars are replaced by the secondary product of decomposition, above alluded to, which is not green enough to be called viridite. These probably represent portions of the base caught up in the felspars. Occasionally in No. 436 the greenish-brown matter appears in rounded forms, suggestive at first sight of pseudomorphs after olivine, but this appearance is, I think, delusive; and the hypothesis that might be based on it is refuted by the general behaviour of this greenish-brown matter and by other considerations. This greenish-brown material apparently forms the base in which the constituent minerals of the rock are imbedded. Moreover these slices contain no serpentine, or serpentinous viridite, and no trace of *Maschen Structur* due to the deposition of opacite, or magnetite, round the edges or along the cracks in olivine crystals, which often betray the original presence of that mineral after its substance has been converted into serpentine. The conclusion at which I have arrived, after a careful study of the Rájmahál slices is that there is not a trace of olivine in any of them.

1—436 Rájmahál Hills. 1—440. "Ball trap." Motijharna.

Viewed macroscopically these are very basaltic-looking specimens, and they would no doubt ordinarily be called basalts. Under the microscope they are seen to belong to exactly the same class of rock as No. 441, described above. Indeed, the difference between them is not one of original structure, or composition; but consists entirely in the relative progress of decay. The amygdaloid was more exposed to the infiltration of water than the less porous lavas, and has necessarily suffered more. As a consequence the zeolites so abundant in the amygdaloids are entirely absent from these two specimens.

As in No. 441, the two rocks under description consist of a mixture of triclinic felspar, augite, and magnetite; and as in the Dubrajpur lava, porphyritic crystals of felspar are imbedded in a ground-mass composed of small prisms of that mineral, and granular augites. In No. 440 the crystals of the ground-mass are relatively smaller, as compared with the large felspars, than in No. 436. Zonal structure, characteristic of the andesitic type of rocks,[1] is common in the porphyritic felspars.

Enstatite-hornblende-diorite.

1—446. Betia Hill.

This is a very interesting specimen. It is composed of the following minerals, namely, triclinic felspar, enstatite, hornblende, magnetite, quartz, apatite, and a little mica. In structure it is perfectly granitic and holocrystalline.

The felspar, judging from its optical characters, is labradorite. It is considerably "schillerized" (Judd), and the included matter is arranged in such regular lines, that in some cases, when low powers are used, it imparts the appearance of fine striation to the crystals.

Occasionally the felspar is so crammed with colourless globulites, and microliths, as to impart a graphic appearance to it similar to some of the felspar in the Dalhousie and Sutlej Valley gneissose granites (*query*, is this eucryptite, or an allied mineral —see Dana's 3rd Appendix, p. 113); at other times rounded microliths of hornblende occur.

The enstatite is about as abundant as the hornblende; it is intimately associated with it, and sometimes it is surrounded by a fringe of the latter mineral.

Magnetite is abundant, and is usually imbedded in the hornblende.

There is not much quartz; and it is evidently the residuum left after the crystallization of the other minerals. It contains some liquid cavities with bubbles.

Apatite is abundant, and is present both in the form of slender microliths and also in good-sized prisms. Mica cannot be detected in the thin slice, but a small packet of undoubted mica was observed on a macroscopic examination of the hand specimen with a pocket lens; it is of dark reddish-brown colour, and an examination of a flake in convergent polarized light showed that it is one of the micas that used to be referred to the hexagonal system.

Andesite.

No. 14—19. Sendurgusi Hill. Sp. G. 2·65.

A compact lava of pinkish colour. It is very rough on the fractured surface, the roughness being produced by its fine-grained porosity; indeed so porous is the rock that the hand specimen, on being plunged into water, continued to give forth streams of air-bubbles for a long time. Owing to the air contained in the specimen, some of which was probably unable to escape, the specific gravity given above is, I dare say, a little too high; but the point is not material as andesites range as low as 2·54[2] and this specimen cannot be much, if at all, lower than 2·6.

[1] Judd: Quar. Jour. Geol. Soc. xlii, 426.
[2] Teall: Geol. Mag., 1883, p. 107.

No. 14—19 was collected by Mr. V. Ball, F.R.S., and it is believed to be a sample of the rock near the Simra Bungalow, described at p. 66 of his memoir on the Geology of the Rájmahál Hills (Memoirs, G. S., Vol. XIII).

Viewed macroscopically this specimen has all the aspect of a trachyte; but as the predominant felspar is certainly not orthoclase (sanidine), it must be classed with the andesites.

To prevent any mistake I had a second slice of this hand specimen prepared, but I have been unable to detect in either of the slices a single crystal of sanidine. The felspar, judged by these slices, is all triclinic; and belongs, like that of the augite-andesites, described above, to the labradorite-anorthite group. It is frequently zoned and presents examples of every form of twinning—albite twins being combined with those of carlsbad, pericline, and baveno.

The rock is composed of a mass of felspar crystals of various sizes (some being comparatively large) imbedded in a devitrified glassy base. The base is much more prominent in one slice than in the other.

The Simra andesite must originally have contained a large amount of magnetite. Some of it has been left in an unaltered condition; but the greater part has been converted into a red oxide; and it is to the presence of the latter in large quantities that the reddish-pink colour of the rock is due.

Olivine is totally absent, and augite is very sparse; being limited to the presence of a few stray, rounded, and corroded crystals. These have apparently not been formed *in situ*, as they are externally very much corroded, as if by an acid magma.

I thought it would be interesting to compare the Rájmahál specimens with the samples of Deccan traps in my possession; and accordingly sliced and examined the following, which are good typical examples from five different, and widely separated, localities.

Deccan Trap.

No. 1—A sub-vitrious lava. Antop Hill. Bombay.

A detailed description of the geology of Antop Hill and of this rock, the "black rock of Antop hill, (?) felstone" of the map which accompanies Mr. A. B. Wynne's paper, will be found at p. 36—40, Memoirs, Geological Survey, Vol. V. It is described as a "black splintery rock." "The whole rock of this hill," Mr. Wynne informs us is "of a curious compact and almost flinty kind," which "differs greatly in appearance from any of the trap-rocks commonly found in the neighbourhood;" but it "reappears at Seoree," and forms "the rock called Cross Island, in the harbour, at a distance of several miles." "Some previous observers thought it resembled an altered argillaceous deposit," but Mr. Wynne successfully combated that notion in his memoir.

Under the microscope this is seen to be a true volcanic rock. It is singularly, fine-grained—finer grained than any lava I have ever before seen; but thin slices under the microscope have none of the aspects of a basalt-glass on the one hand, or of a felsite on the other.

The rock is composed of microscopic prisms of triclinic felspar, and microscopic grains of augite, and magnetite. The microliths of felspar are well formed though minute, and they exhibit distinct fluxion structure in their arrangement.

None of the lavas of Bombay described in my paper in Records XVI, 42, come any where near this specimen in fineness of grain.

The rock does not contain any glassy base—the base being composed of extremely minute granular crystals, possessing low double refraction.

There are some porphyritic crystals of triclinic felspar, and augite, and the slice contains round holes stopped with opal, and a red and greenish substance which may possibly be analcime, or an allied mineral. The slice is also stained red here and there, in streaks, with oxide of iron. We thus see that even an extremely fine-grained, compact rock like this, is unable to resist the penetrating power of water.

No. 2.—Amygdaloid of Pukarni quarries near Harda. A favourite building stone.

This is not a very interesting rock under the microscope owing to the amount of alteration it has undergone. The remains of the magnetite, which was apparently very abundant, may still be seen dotted about through the matrix; but the principal part of it has been converted into the red oxide of iron which has made the matrix very opaque, and has given it a red colour.

The felspar prisms imbedded in the ground-mass are more or less decomposed, and replaced by white products of decomposition; the amygdules are stopped with a zeolite, chalcedony, and opal, and the substance of the matrix is invaded by free quartz and zeolitic substances. The original porous character of the rock has evidently greatly facilitated the alteration of its component minerals.

The general appearance presented by the slice in the field of the microscope is that of a net-work of felspar prisms, imbedded in an opaque brick-coloured matrix, but owing to the progress of decomposition the outlines of the felspars are not sharp or regular. No augite is to be seen.

No. 3.—Ball trap. A very common type all over the Deccan.

This consists of a net-work of triclinic felspar prisms, granular augite, and magnetite, in which ground-mass large crystals of plagioclase are porphyritically imbedded.

The rock, under the microscope, has a very fresh appearance; the felspar and augite, in particular, looking remarkably so; nevertheless it appears to have suffered considerably from the agents of decomposition, for calcite is present in considerable abundance, whilst limonite, and hæmatite, have not unfrequently replaced the magnetite.

An orange-coloured substance is rather abundant, and forms a striking object in these slices, regarding which it is difficult to speak very positively. At first sight it looks like a mineral, but it plays the rôle of a glassy base; it is absolutely without external form or cleavage, and nearly all of it is inert between crossed nicols. Occasionally it polarises feebly in its own natural colour. Closely allied to this is a dark-green substance, which in polarised light is perfectly isotropic. Soaking in hot hydrochloric acid sufficiently long to completely remove the hæmatite, and magnetite, makes scarcely any impression on the orange substance, and little on the green, that is to say, it removes the green colour, and converts the orange into a dull red, but leaves a glass behind absolutely inert in polarised light.

On the whole, then, I have come to the conclusion that both the bright-orange and the dull-green substances, represent the original magma, or glassy base of the rock, and that they owe their mineral appearance to iron colouration.

The larger felspar crystals contain glass inclusions with fixed bubbles. The felspar appears to belong to the labradorite-anorthite group.

No. 4.—This specimen was labelled 'average basalt: One Tree Hill[1] quarries. Belgaum.'

It is a perfectly compact trap, of dark-grey colour.

Under the microscope this is seen to be a fine-grained rock, composed of prisms of plagioclase felspar and granular augite, with some magnetite; in which ground-mass comparatively large crystals of triclinic felspar are porphyritically imbedded. Some of the grains of augite are of considerable size, but none of them show any approach to external crystallographic form.

The remains of the original glassy base, in part of green colour, and in part reddish-brown, is visible here and there. What I take to be the glassy base exhibits undulating marginal lines of colour that follow the borders of the bounding minerals. This appearance has been described by Zirkel in his Microscopical Petrography, p. 234, and depicted in Plate XI, fig. 1, of that work. Zirkel described this substance as the globulitic base of an altered basalt, metamorphosed into amygdaloidal nests. In the case of the Belgaum rock, however, the metamorphism can hardly have proceeded beyond the colouration of the glassy base, for boiling in hydrochloric acid makes little or no impression on it. It has no action on polarised light.

The felspar belongs to the labradorite-anorthite group.

No. 5.[2]—From a dyke more than 100 yards wide, in the Sátpura basin of Gondwána rocks; believed to be Deccan trap, which appears to have once covered the Gondwánas of the Sátpura region (Manual, Geology of India, Part I, pp. 213, 214).

This is a large-grained, perfectly holocrystalline dolerite, exhibiting no trace of a glassy base. Indeed in structure this rock approximates to a gabbro. (Judd, Q. J. G. S. xlii, 62.)

The whole of the felspar is triclinic, and the prisms of which it is composed are massed together solidly, rather than in lath-shaped forms. The augite is granular, but massive; and its mutual relation to the felspar is more granitic than in a true lava. Apatite, magnetite, or ilmenite, and some iron pyrites occur in the rock. The felspar is much altered in places, and the augite is changed along cracks into a fibrous substance.

General Remarks.

For the whole of the specimens described in this paper I am indebted to Mr. Medlicott, Director of the Geological Survey of India. The Deccan Trap samples were received some years back; the Rájmahál ones recently.

[1] Foote: Mem. Geol. Sur., India, XII, p. 182.

[2] Survey number 43-2. The specimen was taken from the bottom of the deep gorge about a mile west of Korángla Hill (2,221 feet, Lon. 78° 42'. Lat. 22°, 34'), on the same dyke, may be 900 feet higher than the gorge. This great dyke, and several others in this field, are many miles in length, and suggest fissure-eruption, rather than volcanic vents. From Korángla a great loop-dyke emerges to the north, and joins again some 5 miles to the west, forming a bow-shaped ring round the Mirakota plateau, of Mahadeva sandstone.—H. B. M.

All the Rájmahál rocks described in the preceding pages, except No. 446, are true lavas. No. 446 (Betia Hill), on the contrary belongs to the plutonic class of igneous rocks; and its perfectly granitic structure shows that it was consolidated at some distance from the surface. Whether it formed part of a dyke; or whether the mass from which this sample was taken constituted the root of one of the Rájmahál craters, it is impossible to say from the examination of this hand specimen. I have not been able to trace any notice of Betia Hill in the Manual of the Geology of India, or in Mr. Ball's memoir on the Rájmahál Hills. I infer from the observations at page 170, Manual, Part I, that Betia Hill was not suspected to be the root of an old volcano; but as the specimen was labelled "*basalt*" by whoever collected it, it might be worth while for some future observer to take another look at Betia Hill. The trap is certainly not a lava. It is a diorite of granitic structure, and very probably indicates the site of one of the old Rájmáhál volcanoes.

A similar remark applies to the Deccan trap specimen from the Sátpura Hills. Though its structure is not so decidedly granitic that the rock can be classed as a plutonic one; nevertheless, it is perfectly holocrystalline and *appoximates in structure* to a gabbro. Clearly the consolidation of the rock, and the crystallization of its component minerals, took place under considerable pressure. The sample was taken from a dyke of great width, shooting up through the Gondwána rocks, which seem nearly surrounded by, and to have been formerly overlain (Manual pp. 213, 214) by Deccan trap; and we have here, I should think, the site of one of the missing volcanic *foci*. Doubtless when the microscopic examination of the Deccan traps in the laboratory goes hand in hand with their close and detailed examination in the field, the general absence of traces of the volcanic vents from which the Deccan and Rájmahál traps were poured forth will no longer be complained of.

No connection between the Deccan and Rájmahál traps has been traced (Manual, xli); and the suggestion of some geologists that the "Rájmahál traps of the upper-Gondwána period, and the Deccan traps are portions of one continuous series of outbursts," is not favoured in the Manual: on the contrary, the conclusion is arrived at, that, "in the absence of any direct evidence, it is premature to suggest that there is any connection between the two formations, or to class them as portions of one great igneous series."

That being the state of the case, it may not be uninteresting to enquire whether the microscope throws any light on the subject. Without intending to imply any intimate connection between the two series in point of *time*, I think the study of the above described samples, though few in number, suggests the probability of their having a deep-seated common origin. The Rájmahál lavas seem to belong to precisely the same type of rock as the Deccan traps. They do not differ, for instance, from each other as the lavas of Aden do from those of Bombay; on the contrary I do not think that any one examining unnamed specimens of the Rájmahál or Deccan traps could possibly say, from any evidence revealed by the microscope, which series he was dealing with.

In all the samples described in this paper, as well as those in my previous one on the "Basalts of Bombay," the entire absence of olivine is a noticeable feature. Olivine is certainly present in considerable abundance in some Deccan traps,

and in some Rájmahál traps (Manual, Geology of India, Part I., pp. 170, 302), though it is specially mentioned in connection with the coarsely crystalline varieties; nevertheless, the entire absence of this mineral in every one of the samples from widely different localities, that I have examined,[1] is a circumstance that seems to possess considerable significance. In the face of it I may, I think, fairly infer that olivine is *generally* absent from the Deccan and the Rájmahál traps; and that when present, it is an exceptional rather than a regular, and characteristic constituent.

In view of this fact, the question arises what are these lavas to be called? They have always, heretofore, from their macroscopic aspect been termed dolerites and basalts. In my paper on the Bombay traps, I said that "a good case might be made out for classing the Bombay rocks with augite-andesites rather than with basalts" (Records, xvi.-49), though I preferred, for reasons stated therein, to retain the name that had hitherto been given to them.

Professor Judd, speaking of the rocks of Fiji (Q. J. G. S., xlii, 427), writes "although both of these rocks have the general aspect of basalts, yet, as olivine is absent from them, I follow the great majority of continental petrographers in classing them with the pyroxene-andesites. I believe this course is practically more convenient than that of extending the groups of basalt and dolerite by including in them the larger part of the pyroxene-andesites." No doubt the presence or absence of olivine is a most important fact; but alas! for the working microscopist, it is the first mineral to decay; and although the original presence of olivine may often be detected when it is going, or just gone; it cannot, I think, be detected after decay has advanced beyond a certain stage without drawing on the scientific imagination more liberally than it is safe to do.

However, as it would be useless to set up a nomenclature of my own, it would seem to follow that the rocks described in this paper, excepting only the enstatite-diorite of Betia Hill, must be called augite-andesites. The Sendurgusi Hill rock, with the aspect of a trachyte, will have to be called an andesite as it contains no sanidine.

[1] I omit from this generalization two or three slides lent me by Mr. Medlicott some years ago. I did not see the hand specimens from which they were taken, or study the slices in detail.

Some notes on the Dolerite *of the* Chor, *by* COLONEL C. A. MCMAHON, F.G.S.

[Received December 23rd, 1886.]

No. 1.—A compact dark-grey rock, very dense and very hard. Sp. G. 3·07. Batteori, Chor Mountain.

No. 2.—A compact dark-grey rock. Sp. G. 3·05. Barela, Chór Mountain.

No. 3.—A similar rock from between Barela and Sohana, Chor Mountain.

None of the above named villages are entered in the Government of India Survey Map, Sheet No. 47. Batteori is on the south side of the Chor, on the road between Nhára (Nara of map) and Tálichoag, both of which places will be found marked on Mr. Medlicott's map (Vol. iii, Memoirs G. S. I.) near the edge of the gneissose granite ("granitoid rocks" of map).

Barela is on the western flank of the Chor, at the edge of the outcrop of gneissose granite, and is, I presume, the place entered on the above mentioned maps as Banallah.

In my field journal I have noted the Batteori rock as occurring in the gneissose granite above the village, and cutting down the hill side in the direction of Tálichoag. The Barela outcrop occurs as a dyke in mica schists, within a few yards of a garnetiferous hornblende rock. This dyke is on the crest of the ridge just above the village, but another outcrop of it is to be found 500 or 600 feet below, just above the bed of the stream. It appears there between beds of felspathic and mica schists, but the outcrop is cut off abruptly at both ends, and does not extend for any distance as a continuous sheet.

Sohana is entered on both the above mentioned maps, in a line between Barela and Tálichoag. I gather from my journals that the outcrop between Barela and Sohana is in mica schist. This rock is evidently the dense trap alluded to in the Memoirs, Geological Survey, III, 42.

I have examined nine thin slices of the above rocks under the microscope, and the result shows that the trap retains essentially the same character throughout. Following the nomenclature adopted by Professor Judd in his recent papers (Q.J.G.S., xlii, 61, 62) it may be classed as a dolerite verging towards a gabbro.

The examination of thin slices under the microscope shows that the Chor dolerite is a perfectly holocrystalline rock. It is composed of triclinic felspar in the form of lath-shaped crystals (namely, small elongated prisms) imbedded in a ground mass of augite which plays the rôle of a magma, or base. Olivine, magnetite, red mica, and apatite, are also component crystals.

The felspar is all twinned on the albite plan; but pericline macles are not unfrequent and baveno twins also occur. Judging from its optical characters the felspar belongs to the labradorite-anorthite group, and more than one species would seem to be present. In one of the Batteori specimens a few comparatively large felspars occur, otherwise they are all in the form of elongated prisms matted together.

Even in the thinnest slices, the felspars are tinted a pale, reddish-buff colour. This seems to be a special characteristic of the Chór dolerite; it is common to all the

specimens described in this paper, and I have not met with any thing resembling this tint in the felspar of other rocks. It is doubtless connected with the presence of a large amount of iron in this dolerite, but the colouring matter is so finely disseminated that the highest magnifying powers applicable are insufficient to determine its source.

"Schillerization" has been set up in all the felspars, and amongst other microscopic inclusions opacite is abundant. These products of alteration, however, are very minute, showing that the process of schillerization had not extended far.

The augite is quite colourless in transmitted light, and is very fresh. It is not unfrequently twinned, but it never shows any trace of external crystallographic form. Club-shaped grains of this mineral are not uncommon.

The most interesting mineral in the rock is olivine, for it is in almost precisely the condition of the black olivines described by Professor Judd, in his paper on the Peridotites of Scotland (Q.J.G.S., xli, 382), the development of opacite, magnetite, or other iron oxide, within the mineral, being due to the process called schillerization. I may note, in passing, that when I showed one or two of these slices to Professor Judd some years ago, he at once confirmed my supposition that the mineral is olivine. In all these slices this mineral presents a uniform character. It is very dark, owing to the development of a fine dust of opacite along certain plains, which dust occasionally arranges itself in very fine lines; at other times magnetite has been developed to such an extent that only small eyes of olivine have here and there been left undecomposed. In some specimens a still further change has set in; namely, the magnetite, or titaniferous iron, has been removed, and a whitish, opaque substance resembling leucoxene has been left behind.

In rather thick slices the olivine is feebly, but distinctly, dichroic; and with the aid of converging polarised light, the double refraction of the mineral is seen to be positive. The olivine is in shapeless grains; and, as is usual with this mineral, though the grains are much cracked, the cracks give no clue to the crystallographic shape of the mineral. These cracks are apparently due to the strain caused by the cooling of the rock at the time of its consolidation, for the schillerization process has been extensively set up along them, the substance developed being a dusty-looking iron oxide, and not serpentine. The latter mineral would doubtless have been formed had the alteration been caused by sub-aerial agencies. Some of the iron in these olivines is certainly magnetite, for it has occasionally segregated in crystals that on being sliced have yielded square and triangular forms.

Apart from the olivine, magnetite is also abundantly developed in the rock. It is frequently surrounded by red mica, which in transmitted light, varies in colour from greenish-yellow to a rich orange-brown. The mica is powerfully dichroic, and belongs to the group that used to be referred to the hexagonal system.

Apatite is abundant in the Batteori specimens.

No. 4.—My next specimen comes from Nhára (Nara) on the south flank of the Chor—the village alluded to above. A little to the south of Nhára, the road from Chaita passes over a ridge running east and west. This ridge is capped with 50 or 60 feet of massive, white, crystalline limestone, weathering grey, which rests on thin bedded mica schists, dipping south, at an angle that varies much within a few yards. The trap is intrusive in the schists and in the limestone.

The microscopic examination of thin slices of this rock shows that it is the same as that previously described. In structure it is perfectly holocrystalline. The augite is more abundant relatively to the felspar than in the other specimens, and both the augite and the felspar are deeper in tint. Apatite, red mica, and magnetite, or ilmenite, are abundant. Olivine is present as usual, but it does not present the dark, dusty appearance of the other specimens. It has been more completely converted, however, into magnetite, or ilmenite, and the white decomposition product of the latter, though characteristic eyes of undecayed olivine, may still be seen in it here and there.

No. 5.—This specimen was collected at Serai, a village on the north-east flank of the Chor, close to the margin of the gneissose-granite. The proper name of the place is, I think, Serañ (silent n), the name of one of the local demons of the Chor, and converted, through piety or ignorance, by a Mahommadan scribe into the Serai of the map. The outcrop occurs as a dyke in thin-bedded mica schists, and is well exposed near a waterfall in a valley to the west of the village.

The very peculiar colour of the felspar, as seen in thin slices under the microscope, shows that this dolerite is the same rock as that which occurs on the south of the Chor. The felspar is disposed to be more massive than in the other specimens; but between crossed nicols it breaks up into well-twinned crystals of triclinic felspar; and, as in the other samples from the Chor, characteristic lath-shaped prisms of this mineral are imbedded in the augite.

Apatite, brown mica, and magnetite are, as usual, abundant; and some epidote is present as a secondary product. Indeed, this specimen is a good deal decomposed. The augite has been in part converted into hornblende and in part into micaceous chlorite. Similarly, the felspar has here and there been changed into a saussuritic mineral, and is invaded, more or less, by micaceous chlorite.

This slice contains no olivine; but I have only one slice, and I cannot lay my hands on the hand specimen. Of the outcrop itself, however, I have a distinct recollection; and I have not only the entry in my journal but a sketch of one portion of the dyke, showing its relation to the schists.

No. 6.—My last specimen comes from Roru, a village 24 miles, as the bird flies, from the Chor in a north-easterly direction. It is situated at the confluence of the Pabar and Sikni rivers, on the road to the Shatul and Borenda passes. The outcrop of the dolerite occurs a little south of Roru, about a quarter of a mile from Serai,[1] as a dyke in mica schists.

The felspar of this rock is all of reddish-dun colour, of exactly the same tint as the mineral of the other specimens. It is a very peculiar colour, and I think it is sufficient to identify the Roru rock as an offshoot of the Chor dolerites.

The structure is more granitic than in the other specimens; the felspar is more massed together; but under crossed nicols it all breaks up—even the more massive looking portion—into long prisms (lath-shaped crystals) of triclinic felspar. The latter mineral belongs to the labradorite-anorthite group.

Augite is abundant, and, as compared with the other specimens, it is grouped more massively. It has been, to a considerable extent, converted into secondary hornblende; and this slice affords numerous and instructive instances of the con-

[1] Not the village alluded to *ante*.

version of the one mineral into the other by processes set up after the first consolidation of the rock. Clear, colourless augite, often presenting its characteristic cross cleavage lines to view, frequently constitutes the kernel of grains, the whole of the outside being formed hornblende. At other times nearly the whole has been converted into hornblende, small patches of clear augite, with well-marked cross cleavage lines, having been left, here and there, in the midst of the hornblende.

It is interesting to note that the metamorphism of the augite is not a mere alteration in the colour of that mineral; but that it involves a complete change in its internal molecular structure and optical properties; thus the converted mineral, as may be seen in this slice, has not only acquired colour and strong dichroism; but a sensible modification has resulted in its cleavage and in the angle of extinction; the angle at which the cleavage lines intersect each other, and the angle at which extinction takes place, differing considerably in the amphibole and in the parent pyroxene that forms the kernel of the crystalline mass. In one case in which the augite is twinned, the external margin of secondary hornblende is also twinned, but the twinning plane has been shifted a little on one side, and is not in exact continuation, or in quite a straight line with the twinning plane of the augite.

Apatite is abundant, whilst ilmenite and mica (part of the latter being of red and part of clear green colour) are present as secondary minerals.

The ilmenite exhibits its characteristic rhomboidal lines; and in some cases the deposit of iron along these crystallographic lines has been so small that the section of the mineral in the thin slice appears as a mere skeleton; the external shape, however, and the internal spaces being very sharply defined. As these spaces are filled with other minerals, the effect produced is clearly not due to the cutting and grinding of the slice; the absence of leucoxene, on the other hand, is opposed to the supposition that the internal spaces are due to decay. The conclusion at which I have arrived therefore is that, in this particular case, the ilmenite is a secondary mineral, and was deposited along with the secondary mica. The secondary character of the latter mineral is clearly seen from the way in which it invades the substance of the felspar.

The felspar and the hornblende in this slice have been to a considerable extent schillerized, though it is possible that the process may have taken place prior to the conversion of the augite into hornblende. The presence of the schiller inclusions has, in every case, either interfered with the development, or the alteration set up has obliterated all trace of the characteristic hornblende cleavage. When the hornblende is clear, it is highly coloured and exhibits characteristic cleavage lines; where the schiller inclusions are abundant, there is no trace of cleavage; in the latter case, double refraction is not so strong; the colour is less marked, and under crossed nicols the polarisation is confused and indeterminate.

The most prominent of the schiller material is an oxide of iron, which when in large grains is red and translucent. It is invariably devoid of crystalline form.

I have not observed any trace of olivine in this slice; but as I have had an opportunity of examining one slice only I do not think it is desirable to lay much stress on this point. Even if a more extensive examination of the Roru outcrop failed to reveal the presence of this mineral, all that I should be disposed to infer from the fact is that it is locally absent: that the Roru rock forms a portion of the

same eruptive mass as the highly basic rock of the Chor I see no reason to doubt.

General Remarks.

The mode of occurrence of the Chor dolerite shows that it is an intrusive and not a contemporaneous eruptive rock, and the examination of thin slices under the microscope bears out the result of field observations. In structure the rock is completely holocrystalline, with a tendency towards being granitic. That is to say, it is more nearly allied to a gabbro than to a lava.

The peculiar colour of the felspar, and the extent to which the olivine is impregnated with iron, are points which may be useful in leading to the identification of the rock in neighbouring localities.

It is now ten years since I visited Batteori, and I have no recollection of the particular outcrop at that village, but I see no reason to doubt the correctness of the entry in my field journal that the outcrop is *in* what we now call the gneissose granite. The exact wording of the entry is as follows—"At Batteori a very dense heavy trap occurs in the granitoid gneiss. I traced it for some distance above the village. It finally cut down the hill side across the road in the direction of Tálichoag." The outcrops at Barela, Batteori, and Nhára, therefore would appear, roughly speaking, to be in a line with each other. Near Barela it occurs in the mica schists, near the boundary of the gneissose-granite; at Batteori it occurs in the gneissose-granite itself; it then edges away from the latter rock, and appears in mica schists at Nhára, and in the crystalline white limestones resting on them.

Corresponding outcrops also appear on the opposite side of the Chor, at Serai (near the margin of the gneissose-granite) and at Roru, distant 24 miles from the Chor. When the neighbourhood of the Chor comes to be explored it will doubtless be found in other places also.

Going hand in hand with the determination of the eruptive character of the gneissose-granite, discussed in previous papers, was the question of age, and there seemed to be good reasons for referring it to the tertiary period. If this conclusion be sound, the dolerite of the Chor would seem to be of tertiary age also, for it appears to be intrusive in the gneissose-granite at Batteori.

The occurrence of highly basic eruptive rocks of undoubtedly tertiary age in the Central Himalayas has already been noted (Records XIX, 115, and references quoted therein); and I think it probable, therefore, that the dolerite of the Chor may be referred to the period of the final building up of the Himalayas.

At many of the places noted in this paper, and at numerous others in the neighbourhood of the Chor, hornblende schists, and amphibolites, occur, which present a strong resemblance to those of the Satlej valley.

I have examined a good many thin slices of hornblende rocks from the following localities; namely, from Nhára, and Barela on the Chor (two of the localities where the dolerite occurs); from Júbal (Jabal of map) about 18 miles from the Chor in a north-north-east direction (the outcrop occurs near the top of the pass leading over into Kotkai); from between Kadara and Sungri (on the mountains that overhang the Satlej to the east, near Nirth); and form the waterparting between the Satlej and the Júbal valleys.

Under the microscope these Chor hornblende rocks and those which form con-

necting links between them and the hornblende rocks of the Satlej valley, are seen to possess common features. Hornblende is the most prominent mineral, constituting the great mass of the rock; quartz, in which a little triclinic felspar is interspersed being quite subordinate.

Garnets, generally of microscopic size, are frequently present. At Barela they are of large size, and abound both in the amphibolite and in the mica schists. Any number of them, of very perfect crystalline form, that have fallen out of the decayed schists, may be picked up on the roadside.

Red mica is very constantly present in the amphibolite and in many of the thin slices sphene abounds. When the latter mineral is not to be seen, magnetite is plentiful; but in the slices in which sphene occurs, magnetite is absent, and its place is taken by a little hæmatite.

Epidote may be seen sparsely in some of the slices.

The quartz is very pellucid, and I have only detected the presence of a few liquid cavities with moving bubbles. They were of extremely small size. Microliths of hornblende were abundant in it.

This rock has evidently been subjected to extreme metamorphism, and it is impossible to determine the character of the original rock from the microscopic examination of these amphibolites.

On the identity *of the* Olive Series *in the* east, *with the* Speckled Sandstone *in the* west, *of the* Salt Range, *in the* Punjab, *by* DR. H. WARTH.

In February last, during a short period of leave, I made a trip to the Salt Range chiefly with the view of extending the observations which gave rise last year to such interesting geological discussions, both local and general;[1] and I was so fortunate as to make a fresh find of fossils which, with other observations, must be taken to determine the identity of the Speckled Sandstone (palæozoic) with the Olive series of the eastern sections, hitherto taken to be cretaceous.

The crystalline boulder-bed in the Nilawán forms the base of Wynne's Speckled Sandstone series. It is only 1½ feet thick, but some boulders are about 2 feet in diameter. Amongst the boulders and pebbles of crystalline rock there occurs a minute proportion of pebbles consisting of soft bluish rock and some of which contain fossils, *Conularia*, *Serpulites*, etc. Such pebbles were found in the boulder bed on the left and on the right sides of the Nilawán gorge opposite the Salt mine, also to the right near the mouth of the gorge. Inside of the gorge the strata observed were the purple sandstone, then the boulder-bed, above that greenish sandstone, then very thick beds of the red sandstone (Wynne's 'Speckled') overlaid by lavender clays and more recent beds. Near the mouth of the gorge there was also seen a remnant of the Magnesian Sandstone, 10 feet below the boulder-bed, recognized by the peculiar lenticular markings described by Wynne at pages 88 and 153 in the Salt Range memoir.[2] About 50 feet lower the *Neobolus* shales were also recognized by the minute white shells which Mr. Wynne first discovered in them at other

[1] *Supra*, Vol. XIX, pp. 22, 127, 131. [2] Mem. Geol. Surv. Ind., Vol. XIV.

places (*l. c.* pages 87 and 142). The position of the boulder-bed at the base of Wynne's Speckled Sandstone is thus quite undoubted.

The fossiliferous pebbles in the boulder-bed of the Nilawán are the same as those found in the Olive Series of the eastern Salt Range. Their occurrence leaves no doubt that the boulder-bed in the Nilawán belongs to the same period as the boulder-bed of the Olive Series in the eastern Salt Range; in fact, that there is one and the same boulder-bed extending throughout the whole of the range.

It is not reasonable to imagine such a coincidence that two boulder-beds should occur in close proximity consisting of the identical crystalline rocks, in each case showing glacial action, and in one case enclosing fossiliferous pebbles, and in the other being accompanied by a regular band of fossiliferous pebbles and nodules with identical fossils, and yet that the two boulder-beds should belong to different geological periods. They must be identical, and the fact of their identity makes the whole boulder-bed palæozoic, because the Speckled sandstone underlies the Productus-limestone.

I noticed distinctly ice-polished and scratched surfaces amongst the boulders further west near Varcha. It is also quite possible that a further search amongst the thicker portions of the bed near Chidru, and other places west of Varcha, might result in the discovery of the facetted boulders known from Mount Chel and other places in the eastern Salt Range.

The identity of the boulder-bed involves that of the succeeding strata, the Olive sandstone series and the Speckled sandstone; the apparent contrast between these strata being easily reconciled. They are, as Wynne states, rather variable, but generally the following may be recognized in descending order:—

Red and purple clays. (Lavender clays.)
Red sandstones. (Speckled.)
Greenish sandstones. (Olive.)
Darker shales.
Crystalline boulder-bed. (Conglomerate.)

The greenish sandstones predominate and are more in view in the east, over the area of Wynne's Olive series, whilst the red sandstones are more strongly developed towards the west, over the area of Wynne's Speckled sandstones. Although less prominent, the red sandstone is distinctly present in the east. During the coal exploration about Dandot, several drifts were worked through these red beds. The purple clay, with its peculiarly crusted surface (*l. c.* p 90), was also well observed at several places.

The red sandstone at Pid contains petrified wood; brown nodules 3 inches thick with calcite, barite and other crystals inside; red sandy calcareous balls, 1 inch thick, often several of them joined together; also small flat discs 2 inches in diameter weathering out, often perfectly circular (once also as a deceptive imitation of a bivalve). All these structural characteristics of the east I found repeated in the Speckled sandstone of the west at Varcha, and some of them also at Nilawán. Instead of difficulty in reconciling the different characters of these rocks, we have thus on the contrary additional evidence which would independently render the identity of the rocks extremely likely.

The correspondence of the two areas leads of course to some discrepancies with certain passages in Mr. Wynne's memoir, but they are all capable of adjustment.

On page 92, No. 8 (the Salt-pseudomorph series) is said to overlie No. 5 (the Speckled sandstone). On page 178, the Speckled sandstone No. 5 is said to be apparently succeeded by the boulder-bed No. 10, but on page 177 discordances caused by slips are spoken of in this section. On pages 104 and 154 bivalves in the Olive series are mentioned as having a cretaceous aspect.

These casual instances cannot shake the strong evidence in favour of identity. It must therefore be accepted, once for all, that the two series are one and the same, and it may be as well to name the united series for the present the *Crystalline-Boulder Series*. This name is all the more suitable because both at the eastern and the western ends of the range the crystalline boulder-bed is the only representative left of the series.

This new united series comprises the whole crystalline boulder-bed of the Salt Range from end to end, all the strata of Wynne's Speckled sandstone, and all the corresponding eastern strata which have hitherto been classed under Wynne's Olive series. This includes all the red sandstones and the highest red clays of the Olive series, probably also the last coarse white sandstone which overlies the red sandstone at several places. Above these would be separated the hæmatite clay and all the shales, sands, and calcareous beds with the coal, or the *Cardita-beaumonti* beds.

An unconformity must then exist between the Crystalline-boulder series and the *Cardita-beaumonti* beds, although the signs of it may not be very evident. Traces of the unconformity may easily be obscured amongst the plastic and crumbling materials which constitute the beds with the coal. It is obvious what the new sequence of the different series of the Salt Range must now be. The following is their order according to Wynne's table, page 69, four of Wynne's numbers being changed; the adjustment will be at once intelligible from an inspection of his diagramatic section, Plate IX.

15. Post-tertiary.
12, 13, 14. Post-nummulitic tertiaries.
11. Nummulitic limestone.
10. *Cardita-beaumonti* beds with coal.
9. Jurassic.
8. Ceratite beds. (Wynne's No. 7)
7. Productus limestone. (Wynne's No. 6.)
6. Crystalline-boulder series. (Wynne's Nos. 5 and 10.)
5. Pseudomorphous salt crystal zone. (Wynne's No. 8.)
4. Magnesian sandstone.
3. *Neobolus* beds.
2. Purple sandstone.
1. Saline series.

Wynne's geological map of the Salt Range shows all these strata in their proper places. It must only be understood that the Crystalline-boulder series is represented by two colours; red with diagonal shading on the left and green on the right. The red comprises the area where the red and speckled sandstones predominate, the green where the Olive sandstones are more prominent. That small portion of green which overlaps the red, really represents *Cardita-beaumonti* beds.

In conclusion we may hope that in due time something may also be found amongst the Talchirs, or near them, to completely establish the truth of Dr. Waagen's more important correlations with regard to the Indian coal measures.

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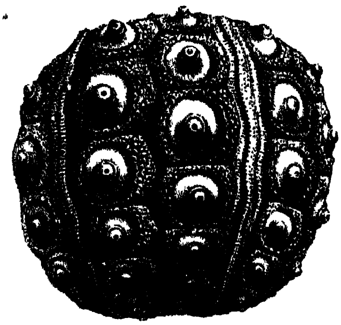

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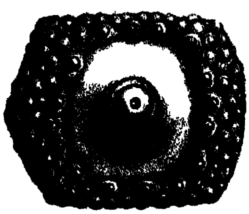

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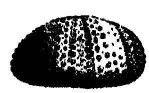

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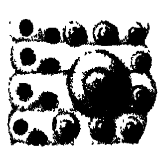

7.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1887. [August.

The Retirement of MR. MEDLICOTT.

Henry Benedict Medlicott, M.A., F.R.S., F.G.S., late Director of the Geological Survey of India, retired on the 27th of April last, after a continuous service of over thirty years in India. He became Superintendent (the title was altered in 1885 to Director) after the retirement of the late Dr. T. Oldham in 1876; and the Annual Administration Reports of this Department, published in the "Records of the Geological Survey of India," speak clearly as to the manner in which he has conducted a Department which was founded and left in complete working order by his predecessor. In collaboration with Mr. W. T. Blanford (then Senior Deputy Superintendent), he produced the first and second parts of the "Manual of the Geology of India," now unfortunately out of print. It is to be regretted that he did not bring out a second edition, or even a new form of the work altogether; but as he has already truly said in his last Annual Administration Report, "to re-write the whole while carrying on the manifold current duties of the Survey has been more than I could attempt in India with any justice to either."

Besides his part in the Manual, Mr. Medlicott wrote five of the Memoirs of the Geological Survey of India, which are works on special formations or districts: but his peculiar genius for conducting a Department like this, and for treating the many and varied questions which came before him as Director of the Survey, is more specially displayed in the Records of the Survey, to which he contributed 44 papers in all. The complete list of his non-official writings, as far as we can ascertain, is as follows:—

"On the Geology of Portraine, county of Dublin." Jour. Dub. Geol. Soc. V. 265, 1850-53.

"On the Sub-Himalayan rocks between the Ganges and the Jumna." J. A. S. B. XXX, 22.

"Note relating to Sivalik Fauna." J. A. S. B. XXXIV, pt. 2, 63.

"On the action of the Ganges." P. A. S. B., 1868, 232.

"On a celt from the ossiferous 'Pliocene' deposits of the Narbada Valley." P. A. S. B., 1873, 138.

"Record of the Khairpur Meteorite of 23rd Sept. 1873." J. A. S. B., XLIII, pt. 2, 33.
"Exhibition of a Meteorite from Raipur." P. A. S. B., 1876, 115.
"Exhibition of Meteorites recently fallen in India, with remarks upon them." P. A. S. B., 1876, 221.
"Remarks on Himalayan Glaciation." P. A. S. B., 1877, 3.
"Note on Mr. J. F. Campbell's remarks on Himalayan Glaciation." J. A. S. B. XLVI, pt. 2, 11.
"Exhibition of the new Geological Map of India." P. A. S. B., 1878, 124.
"Exhibition of some Geological specimens from Afghanistan." P. A. S. B., 1880, 3.
"Exhibition of a specimen of rock-salt from the Chakmani Territory." P. A. S. B., 1880, 123.
"Note on Chloromelanite." P. A. S. B., 1883, 80.
"Note on the Reh efflorescence of North-Western India and on the waters of some of the rivers and canals."
"Lithological Nomenclature." Geol. Mag. IV, 83, 1867.
"The Alps and the Himalayas: a Geological comparison." Quar. J. Geol. Soc. XXIII, 322, 1867: XXIV, 34, 1868; Phil. Mag. XXXIV, 396, 1867.
"On faults in Strata." Geol. Mag. VI, 341, 1869: VII, 473, 1870.

The bald record of his services, as is the custom, is thus given in the official list of officers in the Survey Department of India:—

Engaged by Dr. Oldham from the Geological Survey of Great Britain; joined appointment in India on 24th March 1854; in August 1854 appointed by Court of Directors as Professor of Geology, Roorkee College; re-attached to Geological Survey for the field season; 1854-55, Narbada Valley; 1855-56, Sub-Himalayas; 1856-57, Bundlekhand; 1857 to 1862, Sub-Himalayas; in October 1862 left Roorkee and re-joined the Geological Survey as Deputy Superintendent for Bengal; 1862-63, South Rewah; 1863-64, Behar; 1864-65, Assam; officiated as Superintendent from 21st August to 13th November 1864; leave on private affairs from 10th May to 9th November 1865; 1865-66, Central India and Rajputana; 1866-67, Chota Nagpur, Chhattisgarh, Sumbalpur; placed in the 1st grade on the introduction of grading in May 1866; 1867-68, Garo Hills; 1868-69, Hazaribagh, Sirgujah, Sohagpur, Chanda, Mohpani; 1869-70, Satpuras; 1870-71, Bundelkhand, Narbada Valley; officiated as Superintendent from 20th July to 5th September 1870; sick leave, 13th June to 2nd December 1871; 1871 to 1873, Satpuras; officiated as Superintendent from 16th July 1873 to 15th December 1874; 1873-74, Garo Hills; 1874-75, Betul coal-field, Nimar, Nepal; 1875-76, Nimar, Jamu Hills; appointed Superintendent on 1st April 1876; 1876-77, Mohpani and Satpura coal-borings; 1877-78, Reh Committee, and Nahan; 1878-79, Office, Calcutta; 1879-80, Office, Calcutta; 1880-81, Nahan, and Office, Calcutta; 1881-82-83-84, Office, Calcutta; special leave from 9th May to 8th November 1884; 1884-85, Office, Calcutta; designation changed to Director of the Geological Survey of India; 1885-86-87, Office, Calcutta; permitted to retire on 27th April 1887.

Previous to his retirement, and in acknowledging the receipt of his last Annual Report, his long and valuable services were thus acknowledged by the Government:—

"As this is the last occasion on which the Annual Report will be submitted by you, the Government of India desires to take the opportunity of placing on record its appreciation of your long and valuable services, and to recognise the zealous manner in which you have discharged the duties of Superintendence and Direction and the devotedness with which you have supported the cause of Geological Science in India. I am to add that the marked advance which has been made in the investigation of the geological conditions of India during your tenure of office is most creditable to yourself, and that it is undoubtedly leading to the development of the mineral resources of the Empire, as well as the material extension of scientific knowledge."

Notice of J. B. Mushketoff's[1] Geology of Russian Turkistan. *Compiled from translation and notes from Professor F. Tovla of Vienna, by* C. L. GRIESBACH, C.I.E., *Geological Survey of India.*[2]

The first volume of this work is arranged in two parts: the first part (pages 1—311) being devoted to a review of the results of former explorations, while the second part, from the 9th Chapter, is descriptive of the geological and orographical features of Turán and of the Aral drainage-system.

9th Chapter: From Orenburg to Samarkand. The crystalline rocks of the high steppe between Orsk and Irgis, and in the neighbourhoods of Tashkent, Khojent, and Samarkand, are discussed.

10th Chapter: Treats of the city of Samarkand; the loëss deposits and the nephrite.

11th and 12th Chapters: The western spurs of the Tian-Shán; the palæozoic island Úrda-Bashi, the palæozoic chain of the Kara Tásh, the cretaceous and tertiary deposits on the Sassik and Ak-Tash, the Kaspikúrt range (crystalline rocks and carboniferous limestone), and the valley of the Keless (cretaceous, tertiary, and post-tertiary) are described.

13th Chapter: This is devoted to the valley of the Fergana river (Narin-Sir-Dariyá). Jurassic-beds with coal-seams (Uch Kúrgán) are described overlaid by oil-bearing cretaceous strata (Rishtán) and gypsum and rock-salt bearing tertiary deposits. Two directions of disturbance and flexuring prevail: one from north-east to south-west (the Alai system), and a second from north-west to south-east (the Fergana system). Post-tertiary formations (conglomerates, loëss, bedded sand and drift sand) overlie the tertiary and cretaceous deposits. Permo-carboniferous (Nebraska horizon) underlie the cretaceous formation in Issfara.

14th Chapter: The western spurs of the Pamir-Alai.

15th and 16th Chapters: The Amú Dariyá valley between Chaharjui and Termez, and between Chaharjui and Petro-Alexandrovosk.

17th and 18th Chapters: The deserts of Kizilkum between the Amú and Sir-Dariyá are described.

19th Chapter: A summary of the observations contained in the preceding chapters.

Summary.

Uniformity of geological structure.

Turan presents the appearance of perfect uniformity of geological deposits in spite of the great variety of rocks which have been proved to exist; and this is mainly owing to the fact that the older formations quite disappear amidst the largely developed cretaceous, tertiary, and recent deposits.

[1] NOTE.—"Turkistan, Geological and Orographical descriptions, from observations made during journeys in the years 1874 to 1880.". With a Geological Map of Turkistan, St. Petersburg, 1886 (in Russian).

[2] The present notice comes in as a fitting supplement to the several papers on Turkistan which have appeared from time to time in these Records as the preliminary result of Mr. Griesbach's late Journeying with the Afghan Boundary Commission. The paper is also of interest as referring to country which along its southern boundary just touched on the northern edge of Mr. Griesbach's work along the Khilif course of the Oxus.—(See map ante. p. 93 of first volume of the Records.)

Most of the patches of metamorphic and older formations occur in the Kizilkúm in Central Turán, which forms the watershed between the Sír-Dariyá and the Amú Dariyá or Oxus.

Structure of the eastern margin of Turán.

Beyond the metamorphic and crystalline rocks of the Múgodshár desert, the dioritic island of the Chegana river, and the palæozoic limestones of the Karatan; Mushketoff again met these rocks along the eastern margin of Turán, forming small and quite isolated promontories in the Ūrda-Bashi mountains, which are built up of devonian limestones and granites, while they are flanked by tertiary red conglomerates. In the Karatash range and in Badam carboniferous limestone occurs with the devonians; and the granite of the Ūrda-Bashi is represented by orthoclase and felsite-porphyry with tufa. Kasikúrt is stratigraphically the most interesting island; for besides largely developed carboniferous limestone with numerous fossils, there occur igneous rocks. The isolated hill Monzar is formed of carboniferous limestone. In the Mogoltan range near Hodjénd, coarsely crystalline syenite is largely developed; also porphyritic syenite, diabase, and porphyrite. In Ferghána, Mushketoff found the Karatásh or Kashkaratá hills formed of metamorphic schists and dense diabase.

Further southwards, metamorphic rocks are found near Uratyuba and Jissuk. The Karnak range near Samarkand is formed of slate and diorite; and palæozoic limestones appear in Busgala.

Comparison with the Tian-Shán.

When comparing these rocks with those of the Tian-Shán, a great difference between them becomes at once apparent. The former are much more metamorphosed than the latter. For instance, the minor range of Sultanis-Dagh shows a remarkable diversity of slates, often highly metamorphosed and with many mineral veins; whereas in the Tian-Shán such rocks can only be observed at great intervals and at very few localities. In the Sultanis-Dagh occur rocks, which are entirely wanting in the Tian-Shán, as for instance typical talcose and pistacite slate and eklogite. In the former range, the granites, diorites, and porphyrites show unmistakable traces of metamorphism; whereas in the Tian-Shán this is never the case. The granites too are more closely allied to the Ural granites than to that of the Tian-Shán. Veins of coarsely crystalline granite, containing fine crystals of almandine, beryl, and red schorl, are common in the former area, but quite unknown in the Tian-Shán; on the other hand, the Ural, as for instance, near Múrsinka in the Hinen range, has been long celebrated for its precious stones.

Western margin of Turán.

Similar metamorphic and palæozoic rocks are met with along the western borders of Turán. According to the researches of Messrs. Felkner, von Koshkul, G. Sieners, E. Tietze, and others, crystalline rocks, chiefly granite with porphyrite veins, are developed in the Kure and Kuremin-Dagh hills near Krasnovodsk, which may be looked upon as a continuation of the Balkhán range.

Useful minerals in Turán.

A few unimportant localities of useful minerals are found within the crystalline and metamorphic areas. Besides almandine and beryl, traces of gold and copper ores are found in the granites of the Sultanis-Dagh In the syenites of Mogoltán, some

argentiferous galena occurs, accompanied by green fluorspar. Traces of copper ores are found in the clay-slate of the Ura-Júke. According to Pander, gold and turquoises are found in the granite and porphyrite of the Bukantán hills.

The sedimentary strata of Turkistán. Plant-series.

Mesozoic strata containing land-plants rest on the palæozoic and metamorphic rocks. According to D. Romanofsky, many of the plants found in the mesozoic series of Turkistán are identical with jurassic, others with rhætic, and some even with triassic species. The entire mesozoic series however is of fresh water origin, marine forms being absolutely wanting. Romanofsky believes that Turán formed part of a continent from early triassic to cretaceous times, which extended a considerable distance eastwards. Neumayr looks upon it as the Turánian island in a jurassic ocean.

Jurassic deposits are only met with at very few localities in Turán; but they are of great practical importance since they contain coal-seams. Coal-basins of importance have so far only been found along the borders of Turán, in the valleys of the rivers Bodam, Seiram, and in Ferghána. In the latter area they are well developed. Others may possibly also be found along the western borders; at present they have only been shown to exist in Mangishlak. The jurassic deposits rest invariably discordant on the palæozoic rocks; whereas the cretaceous strata and tertiaries are usually conformable to them. Only locally is there an unconformity visible between the jurassic and the overlying cretaceous formations.

Cretaceous and tertiaries.

The cretaceous and tertiary deposits are the principal rocks of Turán where they reach an enormous thickness; altogether about 2,000 feet in Ferghána and 5,000 in Hissara. They are always closely connected and are conformable to each other. The stratigraphical features are most complicated in the hill-ranges, especially in Keless and in Ferghána; but the further away from the hills of Eastern Turán, the simpler becomes the structure until, in Central Turán, the strata are perfectly horizontal; an exception forms the Sultanis-Dagh and Bukantan (in Kizilkum), where a north-west strike prevails.

The lithological character of the cretaceous deposits varies considerably. Where they are well developed, they consist of a great thickness of bright-coloured beds of gypsum, clay, marls, and shell-limestone, with micaceous and ferrugenous sandstone. The sandstone, limestone, and marls are remarkable for their regular development, whereas the clay-beds and gypsum deposits often thin out at short distances. The first group of rocks is found all over Turán, the other only in the Tian-Shán, Pamir, and Alai; in Ferghána, for instance, the complete series of rocks is found; whereas only the first group of beds occurs near Kilef on the Oxus.

Away from the eastern hill ranges the lithological character of the rocks becomes modified—the shell limestone passing into oolitic and dense limestones, and the bright coloured (red and green) micaceous sandstones becoming more uniformly light grey and yellowish coloured. The fossils are mostly so badly preserved that a division of the Turánian cretaceous group into horizons is hardly possible. Romanofsky divides the cretaceous group into two horizons, namely, an upper or Ferghána formation, containing numerous species of ostrea (near the Oxus mouth some Ammonites of senonian types also occur), and a lower horizon characterized by some ostrea, rudistes, echinderms and a few brachiopods. In Ferghána, the creta-

ceous formation yields naphta, especially at points where there is a change in the strike of the beds. According to Konshin, the naphta and ozokerite of the Western Turán belong to a younger geological horizon than the Ferghána deposits.

Tertiaries.

The tertiary deposits are closely connected with the cretaceous group in central Turán; they are unfossiliferous in the spurs of the Tian-Shán, casts alone occurring and then only in a very few beds. Nummulitic limestones occur on the Aral, but are not found elsewhere in Turkistán. They are overlaid by lower and middle oligocene fossiliferous deposits (sandstones, clays, and limestone), followed by miocene limestone and sarmatic clays.

The tertiary series of the Tian-Shán is poor in fossils and can scarcely be divided into separate horizons. Romanofsky believes that eocene, oligocene, and miocene formations are represented, overlaid by a largely developed pliocene formation.

As eocene, he considers strata with *Sphenia rostrata*, Lam., *Modiola subcarinata*, Lam., *Modiola jeremejewi*, Rom., and *Avicula trigonata*, Lam. From the oligocene he cites: *Alligator darwini*, Ludw., *Ostrea raincurti*, Desh., *Ostrea longirostris*, Lam., &c.

The miocene and pliocene chiefly consist of conglomerates and sandstone beds, and are closely connected with the younger Aralo-Caspian formations. A characteristic *Valvata* is found in the largely developed pliocene deposits.

It was observed that the tertiary formations also change in lithological character further away from the hills; the shell-limestones disappearing and being replaced by sandstones. The green gypsum and rocksalt-bearing clays which are so largely developed in the east gradually thin out westwards, and the great salt deposits disappear altogether. The coarse conglomerates pass into fine-grained varieties.

According to Mushketoff, it appears that the tertiaries of the Tian-Shán have been deposited near a coast line; whereas those of the Aral neighbourhood are of purely pelagic nature. He believes that the nummulitic sea had a considerable depth which gradually decreased in the following periods: for instance, the Ust-Urt became dry land during the sarmatic epoch, whereas the lower Sir-Dariyá and Oxus regions remained a marine area till pliocene times.

The pliocene marine area was the forerunner of the present Aralo-Caspian basin, which gradually broke up into several smaller and isolated lake-basins, many of which exist to the present day, although constantly lessening in size and depth.

The entire series of formations, from the cretaceous to the younger tertiaries, forms one connected whole in which the boundaries between the several groups are exceedingly obscure, owing to the gradual changes which took place during the deposition of the series. During the whole period of time, from the cretaceous to the pliocene, Turán was covered by a sea, which spreading over the jurassic continent existed at first as an open ocean. This gradually changed to a mediterranean sea; and after deposition of the sarmatic detritus, it became a completely land-locked basin, which steadily lessened in extent until it is now represented by several isolated lake areas.

The stratigraphical features prove that contemporary with this change in the extent of the ocean area, an uninterrupted process of folding took place in tke surrounding land area; the outlines of the present hill ranges having begun to form before the deposition of the cretaceous formations.

The Aralo-Caspian deposits are of very varying thickness. Generally they are yellow or greyish-blue sandy clays with fine, often false bedding, completely corresponding lithologically with the upper deposits of the Kalmück desert. The brown and dark blue clays and white quartz sandstones of the Caspian deposits are entirely wanting in Turán.

The fauna of the Aralo-Caspian formations agrees with the living fauna of the Aral and Caspian seas. *Cardium edule*, L., *Dreyssena polymorpha*, Van Ben., *Neritina liturata*, Eichw., *Adacana vitrea*, Eichw., *Hydrobia stagnalis*, L., *Anodonta ponderosa*, Pfr., and a sponge, *Metshnikowia tuberculata*, Grimm, were found in Karakum, north-east of the Aral. These are forms, which in the Caspian live close in shore, in depths at most of 8 fathoms: *Cardium edule* being alone found at greater depths. *Hydrobia stagnalis*, *Metshnikowia tuberculata*, and *Anodonta ponderosa* live at still lesser depths. Nearer the Aral was found *Lithoglyphus caspius*, a species which occurs in the Caspian at the present day at depths varying from 7 to 108 fathoms. The Aralo-Caspian deposits in Turán are to be considered therefore as shallow-water formations.

Grimm has shown that the distribution of the living fauna of the Caspian is closely connected with the existence of great deposits of drift-sand. Where the coast-line is influenced by waves of drift-sand, he found animal life almost entirely wanting, a fact which, as Mushketoff believes, explains the sporadic occurrence of fossil remains in the Aralo-Caspian deposits.

The boundaries of these deposits can only be observed here and there. According to Mushketoff (contrary to the opinion of Barbot de Marni), the Ergeni hills west of the Caspian formed the old shores, and near the parallel of Manytsh a narrow channel formed a connection with the Pontus. Ust-Urt and the Mugojár range partly interrupted the connection, forming a long and narrow promontory in the Aralo-Caspian sea, and thus divided it into two separate basins. Sewerzoff thinks that the eastern basin may have reached as far as the Balkash lake; whilst to the southward the parallel of the Sultanis-Dagh may have partly formed the boundary.

The western and larger "Caspian" basin was the deeper. The channel which connected both runs between the two Bálkhan ranges; therefore along the Usboij to eastwards, into the so-called Sarykamish basin which was again connected with the Aral-basin through the strait of Aybugir between the Ust-Urt and Sultanis-Dagh.

Mushketoff expresses himself decidedly against Grimm's opinion that the Usboij was the former course of the Oxus.

Climatic changes brought about, and are still active in bringing about, the narrowing of both sea tracts of the Aralo-Caspian area; the disappearance of the channels of communication between both basins having been the first step in the direction of this shrinkage.

Mushketoff divides the drift-sand into two kinds, which form the littoral and the continental areal deposits.

*

Dry and cold north and north-east winds are the prevailing air currents during the dry seasons (summer and autumn); they absorb moisture, even such moisture as the soil may receive from rain and snow during the remainder of the year. This accounts for the rapid destruction of the cretaceous and tertiary sandstone, the decomposed material of which is carried away by the air currents of the dry seasons and re-deposited in the deserts of the Oxus and Sir-Dariyá.

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal, and Kumaun. Section I, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India* (with map and plate).

INTRODUCTION.

Although much has been done recently, by Colonel McMahon, to bring to light the structures of the gneissose and other crystalline rocks of the N. W. Himalaya, and to frame reasonable hypotheses as to their cause, it must be admitted by every one who has looked into the subject that much yet remains unaccomplished. Microscopical work of high order, and detailed sections carried along one or two lines of country, are of the greatest service to geology; and the value of the papers which Colonel McMahon has from time to time contributed to this journal cannot be over-estimated. But for the rational account of an expanse of crystalline rocks something more is wanted which the above cannot supply; I refer to the actual tracing, step by step, of their relations in the field, or in other words, a patient mapping of the district on an adequate scale. Petrography at the present day is in such a state of transition with regard to many of its most vital principles, that the reading of any one district by the petrographical alphabet made out in another should be supplemented by deliberate endeavour to ascertain how far that alphabet can apply to the district, and by how much it falls short. With this end in view, it seems to me that fairly detailed descriptions of the arrangement, internal structure, lie, and associations of the crytalline rocks of this part of the Himalaya, drawn from exhaustive field observations, will constitute the safest and most impartial evidence attainable in the great questions always pressing for solution among crystalline and metamorphic rocks. I therefore propose to describe here and subsequently a series of localities where these rocks appear to show to the best advantage, the descriptions in

all cases being based on a thorough mapping of the area on the one inch scale. There will then be no need for elaborate argument and careful balancing of probabilities; each locality will tell its own tale, so far as structure, lie, and behaviour of the rocks can tell it; each district will depend entirely on its own internal evidence alone, and I shall endeavour as much as possible to banish the risky proceeding of generalizing over large areas. Detailed field exploration is the basis of geology, and sooner or later will extract the secrets from the rocks; and that without recourse to interpretations borrowed from other countries, which may be, but are equally likely *not* to be, applicable, and without appeal to principles and theories supposed to be universally accepted, but which may be after all only partially true.

DUDATOLI MOUNTAIN, BRITISH GARHWAL.

I will begin these descriptive notes by an account of Dudatoli Mountain and its surrounding spurs. I have already mentioned it in a previous number of the "Records," but without giving any details.[1] This mountain, which rises to the height of 10,188 feet, constitutes the source of the Ramganga and the east and west Nyar rivers, all of which are tributaries of the Ganges. It is by far the highest mountain in the neighbourhood. Most of its upper slopes are covered with dense forest of pine, with an undergrowth of Ringall reeds; snow lying for a great part of the year among its sheltered and rocky fastnesses. Without implying more than is directly stated, I may say that it bears a very strong resemblance to Kalogarhi Mountain[1] (Kálandanda) situated further to the south-west and near the plains and also to the Chor Mountain near Simla; both in the way it rises above the surrounding country and in its geological structure.

Geological structure.

Speaking roughly, Dudatoli and its neighbouring hill spurs may be said to be composed of two sets of rocks, namely, mica schist and gneissose granite. These vary among themselves and shade off into different varieties which will be mentioned in due course. Their general surface arrangement will be seen from the accompanying map. The structural features are those of a quaquaversal synclinal elongated in the direction north-west—south-east. The uppermost and lowermost beds are schists of varying character; whilst the gneissose granite appears at numerous horizons insinuated among the schists, seemingly bedded with them, but in lenticular beds which expand or thin out with extreme rapidity. On the east, south, and west sides these lenticular beds are very prominently developed, whilst on the north there is only one thin but continuous band. The Dudatoli ridge itself is very nearly uniformly composed of the gneissose granite, the one or two thin bands of mica-schist which intervene being very unimportant. East of a line between the two Dudatoli peaks, the gneissose rock rapidly breaks up into a fringe of thin beds whose foliation planes dip roughly towards the south-west. They ultimately thin out altogether. West of the two peaks there is one blunted protruding mass in the direction of Gulek, whilst the long thin band alluded to above passes from Dobri trigonometrical station by Tarakakand, Banjkot, and Kotkhandia trigonometrical stations, and the villages Sountee and Hartur. Near the last mentioned place it is interrupted by a fault, but apparently was originally continuous into re-connection with the Dudatoli massif by means of the band

[1] Records, XX. pt. 1, p. 40.

which now runs along the Bandi ridge. This tongue of gneissose granite has thus almost completed an ellipse of outcrop, and from the quaquaversal dip can only indicate a continuous sheet beneath the schistose strata of Naori which are the highest beds visible of the series. Apparently below this continuous bed there are several more lenticular masses of the gneissose granite inserted between the schistose strata, but only outcropping on the south side of the synclinal. They rapidly thin out towards the north-west beyond Duiukatoli and gradually coalesce for the most part towards the east-south-east and join the south extension of the Dudatoli massif. South of Kainur there are one or two very thin beds which run for a short distance and thin out both ways. If they have any connection with the main mass of the rock it must be a subterranean one.

I have already called attention to the like disposition of the similar rocks at Kalogarhi Mountain and at the Rama Serai,[1] and I here lay especial stress upon the fact, because in a line of section from the Sub-Himalayan boundary to the snows running through Kalogarhi, Dudatoli, and Kedarnath, the only regular apparent synclinals of any importance are connected with the gneissose and schistose series. Nowhere except on the north side of a mass of gneissose granite is there ever a prevailing south dip of the strata. This may be either a coincidence or a necessary relation. I leave the question at present to be afterwards returned to.

Schistose series.

I now come to some of the most marked features in the schistose series, which forms as it were a groundwork for the gneissose granite. Over a large area these rocks consist of the more arenaceous, or quartz-schist type with thinner dividing beds of more argillaceous schists; the schistosity being not very marked. Foliation takes place in the majority of cases along the original bedding, as is well demonstrated, where the arenaceous and slaty types interbed. In some few cases however I found it crossing the bedding along incipient cleavage planes, especially in some quartz-schists; whilst films of mica were often visible along joint planes. In addition, wherever the rocks had been much crushed and cut by nearly parallel divisional planes and by slickensides their surfaces were also coated with a thin micaceous glaze. In some cases among the quartz-schists laminæ more or less micaceous had been cleaved across, and the mica plates re-arranged perpendicular to the laminæ where they occur. To whatever cause this regional metamorphism be due, it is certain that it begins imperceptibly and continues with a minor degree of intensity over a large tract. The section from Shánkar on the Ramganga due north to near Hansuri on the east Nyar plainly demonstrates this. About a mile from any outcrop of gneissose granite as we approach the Dudatoli massif, in no matter what direction, there is a rapid, but gradual change sets in in the metamorphism of the schistose beds. The faint films of micaceous material assume by degrees the aspect of distinct layers of mica plates of considerable thickness. Vein quartz appears ramifying along the foliation planes. Garnets gradually assemble in the schist; first showing as minute pin-heads under a coating of what one may call mica-leaf, and gradually increasing in size and definiteness concomitantly with the mica until they reach an average size of peas, and rarely as large as filberts. On every side of the Dudatoli area can these most

[1] Records, XX., pt. 1, p. 30.

striking changes be observed. In the present paper I am only offering evidence collected in the field, and consequently confine my observations to what is visible under a pocket lens or to the eye.

Varieties of the schists.

The more intensely crystalline schists may, as a rule, be divided into two kinds from a structural point of view. The more common type is one in which the planes of foliation have a wavy or blistered appearance, and are completely covered with mica of a pale silvery hue. The leaves of mica are, as it were, welded together along the wavy irregularities of the foliation planes, forming an uninterrupted layer of the shining mineral. Under the lens the garnets are of a dull claret colour, and when not mere grains are of a more or less distinctly crystalline form. The break of continuity along the foliæ, caused by a garnet, is always overcome by the mica plates waving round it on both sides. Nevertheless, I also found other plates which ran undisturbed towards the garnet, and then stopped abruptly (see fig. 1). The quartz, which in this type is very subordinate, is of necessity present in lenticular layers between the waving sheets of mica. Secondary quartz, in large lenticular or nodular strings, enwrapped in a thin tissue of mica, is frequently met with. The other type of schist is a much more quartzose rock, and is regularly bedded with the former. The mica in this case does not cover in, in a complete manner, the foliation planes. Instead, it is disseminated in small flakes, and is of silvery hue, and also brown. At the same time, their arrangement is always parallel with the bedding, causing a genuine foliation. Garnets are scarcer than in the former rock.

The first of these two types is only rarely puckered or corrugated. Near Malkori pass south-east of Dudatoli there is a variety in which the mica plates, with a leaden sheen, have the appearance of shrivelled tea-leaves. A rather singular structure arrested my attention in the schistose beds as they are advancing from the widely spread slightly schistose kind to the more intensely metamorphic border round the gneissose granite. The foliation surfaces, which were very regular, straight planes, shewed a set of parallel ridges and furrows running in the direction of the dip. They were very minute, and a good idea of the effect to the eye may be obtained from the aspect of a corrugated iron roof.

I may here emphasize two points—first, the schist found near the gneissose granite is entirely a thorough crystalline schist, a fact needing no microscope to demonstrate; and secondly, along a line of country, where rock is exposed at every step, it is seen that this culminating intense form *graduates* into a wide-spread less intense form, and that in turn *graduates* into ordinary slates and quartzites.

From the universality of the changes as the gneissose granite is approached, it is only reasonable to conclude either that the extra schistosity and the development of garnets were brought about by the introduction of the gneissose granite (in whatever way the latter was produced), or that they and the gneissose granite were the joint result of some more remote and subtle cause. In any case, the two rock states are so inseparable that they may be classed as contemporary. It follows that whatever can be proved concerning the geological age of the one may be taken as evidence for the age of the other. The importance of this will be noticed in a paper to follow.

I was unable to gather any clue from the manner of occurrence of the garnets,

The bending round of the mica plates does not satisfy me as an argument for the priority of crystallisation of the garnets.[1] I may, however, say that the latter in all their stages, from the minutest speck to the fully crystallised form, were always intact: there was no sign of crushing or drawing out of them with the foliation. Perhaps a microscopic examination may yield more decisive results.

Gneissose granite.

Turning now to the gneissose granite of the Dudatoli neighbourhood, it is necessary to sry something of its mineralogical composition. In this I shall be brief, partly because the rock seems to answer perfectly to much of the allied rock already so luminously described by Colonel McMahon, and partly because the object of this paper is rather to draw attention to the larger aspect of the rock in the field than to its microscopical character. At the same time, I may point out that its coarsely crystalline condition makes the examination under the lens not so hazardous and superficial a matter as it might otherwise appear. It must be borne in mind that I am speaking at present of the rock in this locality of Dudatoli only.

The rock as a whole may be said to be eminently felspathic, and distinguished from an ordinary granite or gneiss by the presence of schorl crystals. These latter occur in all manner of conditions, from large to small, from perfect prisms to others which are manifestly severed portions of a single prism, and held together like a string of beads. The schorl is the most completely crystallised of the minerals; the micas, black and white, come next, often constituting the only perfectly crystallised minerals in the rock. Orthoclase, in rectangular prisms sometimes twinned, is not typical in the rock, but usually appears as in an "augen" or kernel gneiss. The quartz as in all granites is always without crystalline form and fills the interstices between the other minerals. In many cases minute granules of quartz and small portions of schorl are contained in the larger porphyritic orthoclase crystals and "eyes." Garnets occur very sparingly, sometimes singly and sometimes in nests. Kyanite, Beryl, and other accessory minerals I am confident are not present in this locality.

This outline is sufficient to shew the general mineralogical resemblance between this rock and others described by numerous writers on other parts of the Himalaya.

In themselves the minerals are not so important as in their mode of arrangement which varies so conspicuously in different parts of the same mass of gneissose granite that it requires very special mention. In describing these I may add that they are paralleled nearly always in the Chor and Kalogarhi Mountains; but at Kedarnath we come upon rocks of an altogether different structure, and none of the remarks to follow will consequently apply to the gneissose rock of the snowy range where I have at present seen it. The latter better agrees with Stoliczka's "Central gneiss"[2] or what Fouqué and Lévy call "gneiss granulitique."[3] I hope to describe it later.

Varieties of the gneissose granite.

The Dudatoli gneissose granite for the purpose of classification easily divides up into three types—(A) FOLIATED, (B) SEMI-FOLIATED, (C) NON-FOLIATED. These three all graduate one into the other.

(A) may be sub-divided into (1) *Tabular foliated*, (2) *Lenticular-Tabular foliated.*

[1] See Minéralogie Micrographique, Fouqué and Lévy, Manche III., fig. 2.

[2] See Mem. G. S. I., V., pt. I, p. 12.

[3] Minéralogie Micrographique, p. 175.

(A) (1) is a variety not often seen in this part, and then only near the junction with the schists. It is the most decidedly fissile of any of the varieties, It is built up of continuous straight foliæ of felspar and quartz, with intermediate foliæ of mica in continuous films. These each run their own course at least for a great distance without coinciding, the mica being very generally muscovite only. To the weather and to the hammer this rock behaves more like a schist than a granite (see fig. 2).

(A) (2) is much more common, especially in the thinner bands of the rock, which occur near the outskirts of the gneissose granite area. In it the felspar is still undifferentiated into eyes or crystals; but the foliæ of felspar and quartz swell out and thin again (see fig. 3), foreshadowing the perfect eyes of the prevailing forms of the gneissose granite (see B). In using the words "undifferentiated" and "foreshadowing," I by no means imply that the lenticular-tabular is necessarily an embryonic condition of the augen. It seems as likely that the reverse is the case, for in some quartzites of coarse grain, between Rudarprayag and Agastmundi, I have seen the grains, originally rounded, absorbing smaller portions of quartz at each end and so taking on a lenticular appearance, which with the mica films developed coincidently gave the appearance of a lenticular-tabular quartz schist (see fig. 5).

(B) may be sub-divided into (1) *Augen*, (2) *Porphyritic-augen.*

In (B) (1) the different mineral layers are no longer distinct. On the contrary, the mica plates of two layers unite with each other on each side of an "eye," thus cutting up the felspathic layer into a number of isolated eyes (see fig. 4). The long axes of the eyes being parallel give the semi-foliated character to the rock. Connected with this sub-division is a rock, which on the foliation planes shews eyes of felspar blotched and drawn out in the direction of dip. It and the lenticular-tabular quartz schist mentioned above seem to indicate differential movements of the particles of the rock, and are paralleled by structures in other basic rocks, which I hope to describe in another number.

(B) (2) only differs from (B) (1), by containing, in addition, larger, more blunted eyes at intervals, very often turned in directions other than parallel with the foliation and sometimes approximating to a rectangular outline. This sub-division is the most developed of any at Dudatoti, the Chor and Kalogarhi.

(C) in all respects resembles a normal granite, and is usually porphyritic, the porphyritic crystals being always sharply rectangular and often twinned. They are oriented in all directions.

General facts of distribution.

The result of a careful examination of the Dudatoli area is to shew that the sub-division (A) (2) is nearly always found in the thinner bands of the rock, and in the thicker ones near the junction with the schists. The division B is found impartially in all but the thinnest bands. The division C is only found in those parts where the bands of gneissose granite have united together to form a wide continuous mass, and then only in small quantities compared with the division B. These results may be shortly stated by saying that the more the rock loses its bedded appearance the more it approaches a massive and perfectly granitic form; whilst wherever it alternates rapidly by interbedding with the schists, the foliated and semi-foliated types predominate.

Inter-relations between the schists and the gneissose granite.

I must now advert to a consideration of the inter-relations between the schists and the gneissose granite. These are of such great importance in understanding by how much the latter has acted functionally as an intrusive rock, are so amply demonstrated by close work with the hammer, and may hence be said to be the field-geologist's speciality, that I make no apology for treating them fully in this place. The gneissose granite of Dudatoli, in no case that I know of, breaks through the schists, disturbing them: no violent contortions, no puckerings of the foliation planes ever take place as distinct results of the intrusion of the gneissose granite. The difference between this rock and a genuine intrusive granite with large masses of muscovite, which very rarely occurs in the Dudatoli area, and which by the fact that it has no passage forms towards the gneissose granite may be considered to be entirely distinct and doubtless of another geological age, is most marked. A block of mica-schist containing the latter is penetrated irregularly by an amœbiform mass of it which at every thrown-out process or vein has crumpled and tortured the schist into utter compliance with its own irregularities of shape. Compare this with the thin band of gneissose granite near Hansuri, thoroughly exposed in the river section. Its upper and lower surfaces are perfect planes fitting in with similar planes in the mica schist. If the former rock had been sawn in a mason's yard and fitted in with artistic precision, it could not present a more composed aspect, both in its own regular structural planes and in those of the mica schist among which it lies. And yet the two rocks are so unlike that a pencil point may be placed precisely on the junction line. Or consider again what looks on the map a contradiction to the statement of its non-eruptive character, *viz.*, the blunted process near Gulek. At Burari the dip of the foliation of the gneissose granite is S.-W. 30°; and that of the schists in contact is perfectly parallel. Following the junction boundary north-west, there is, near Risti, a more westerly dip in the gneissose granite; and this is also conformed to by the schistose beds. East of Gulek the dips of both have worked round towards the north-west, still retaining their concordancy. Similarly, if the boundary line be further examined, turning towards the north and north-west below Dobri trigonometrical station, it will equally be seen that there is no sudden intrusion, no erupting of the one rock among the other, but on the other hand that each has its foliation planes perfectly parallel with the other, and there is no contortion or puckering of the mica-schist whatever. Without going into detail over the whole map, I may summarily state that everywhere, except where a fault is manifest, the lie of the one rock coincides completely with the lie of the other: such an event as the foliation lines of one crossing at right angles the foliation of the other is unknown.

That the foliation represents true bedding, is placed beyond a doubt by the numerous river sections where from a great height the interbedding of the two rocks can be traced conforming to the trend of the foliation planes. Thus the gneissose granite is *insinuated* among the schists; and if it is intrusive from a foreign source, and not inborn, it must have acted on the principle of the wedge and parted the schists with wonderful precision along very great distances. At Kalogarhi the same remarks apply.

Junction exposures.

The individual beds of the gneissose granite are, as a rule, sharply marked off from the mica-schist, although a large bed nearly always splits up into numerous smaller ones near the schistose margin. These cannot be rendered on the map. An exception to this rule at Eera village is very striking. There the schists merge into the gneissose granite by the gradual acquisition of felspar. This takes place in such minute quantities at first, in the form of small veins, that it is impossible to say where the one rock ends and the other begins. The same conditions are repeated numberless times; so that only diagramatic mapping can be attempted there.

The junction section at Marwara needs a few special remarks. The gneissose granite of (B) (2) type does not fade away into the schist, but it stops abruptly and is followed by a pure mica-schist composed of bronze-coloured mica and quartz. But among the mica-schist next the gneissose granite there are thin beds, 3 or 4 inches across, of fine-grained gneissose granite, very sharply cut oft from the mica-schist. There may be a dozen or more of them (see fig. 6). Notwithstanding their thinness, porphyritic crystals of orthoclase are developed, often filling up the whole of the breadth of the band, and even where too large slightly bulging out the walls of mica-schist.

One more junction structure, well marked at Byansi, is that of a mica-schist as a ground-work, in which large porphyritic eyes of orthoclase are developed singly or in strings. The schist is fine-grained and the eyes of orthoclase stand out in bold relief. In other parts of the Himalaya I have seen this doubtful form prevailing almost to the exclusion of any other.

Inclusion in the gneissose granite.

I have only seen one included fragment of rock in the Dudatoli gneissose granite. This was in a large torrent boulder in the stream below Kainur. The boulder was of the porphyritic augen type, and the included fragment of mica-schist of the more arenaceous kind (see fig. 7). Doubtless more exist, but I am inclined to think they are by no means plentiful. A cursory examination of the Chor in 1884 revealed several examples of inclusions of schist and quartzite; whereas more detailed work at Dudatoli has only been rewarded by one find.

Geotectonic features.

Returning to the geotectonic features of the area, the problems expressed in the present synclinal arrangement of the beds are many. The certainty that at some period there must have been a folding of the rocks leading up to the synclinal, provokes the question whether this earth-movement took place before or after the introduction of the gneissose granite. If before, then we have to account for the latter choosing a widespread synclinal oasis as the place at which to escape from its plutonic confinement; if after, we must seek for the influence, which the gneissose granite possessed, in holding in check the waves of flexure, which setting in from all sides seem to have subsided so conspicuously before the gneissose granite, here, at Kalogarhi and at the Rama Serai. One other alternative, that they were contemporaneous, remains. Can the waves of contortion, meeting at this point, have neutralized one another's sensible movements and thereby induced the movements of particles and of molecules, causing cleavage, heat, and metamorphism?

In endeavouring to look these questions in the face we have the following facts to go upon:—

(1) Plutonic and metamorphic action by their deep-seated nature cannot be said to be influencing the Dudatoli area at the present time, nor to have done so in the immediate past.

(2) A wave of contortion of the strata, resulting in a quaquaversal thrust plane round the Kalogarhi centre, in post-nummulitic times, was proved in my last paper (Rec., XX, pt. I); whilst successive waves of longitudinal flexure, at still more recent dates, involving last of all the Siwaliks, have long been acknowledged as affecting the whole of the Himalaya.

From these considerations it seems that the crystalline rocks of Dudatoli must have long ago finished their metamorphism, whilst they have continued to suffer tangential pressure all through tertiary and recent times, if not from a more remote period. I am aware that Colonel McMahon holds to the late tertiary age of the gneissose granite of other parts of the Himalaya; but speaking of the parts of Garhwal and Kumaun with which I am acquainted, I fail to see how a rock of *deep-seated origin*, like that of Kalogarhi at a present elevation of 6,000 feet, can by any possibility be later than tertiary strata *in the same locality*, prominent for nothing so much as their uniform restriction in height to between the 3,000 and 4,000 feet levels. (See map, Rec., XX., pt. I.) And further, from their forming that prominent feature on the plain-ward side of the hills, to which the name Sub-Himalayan has been given, out of which they stray markedly neither in an upward, downward, nor lateral direction, it would be unreasonable to urge that they might have once covered much of the Himalayan region, and that their present state is but an infinitessimal relic of their former wide extension, dropped or forced low by faulting. That reversed faulting has in a manner tended to preserve them when they would otherwise have perished much more by denudation I have no doubt; but looking at the tertiaries in a broad comprehensive light, it is manifest that their position on the plain-ward edge of the hills at a uniform height and extending for hundreds of miles thus, is analogous on a large scale to a raised beach or high level gravel only *modified* by subsequent faulting. This is in substance what Mr. Medlicott has always advocated.[1] Pushing home the argument still further there is a step-like arrangement among the individual members of the tertiaries; for the oldest is usually in the highest position and reaches further into the Himalaya, whilst succeeding younger members stand at lower levels and nearer the plains, the last of which the Siwalik fronts the plains and rises out of them to a comparatively low elevation. Hence it is clear that each lateral thrust of the mountain area since nummulitic times caused, or was accompanied by, a further rising of the margin of the hills; and the tertiary deposits were stranded, one after the other, in positions varying in height according to their age.

To urge that the gneissose granite of Kalogarhi, at 6,000 feet, could have been formed during this tertiary period of steady periodical rise, is akin to claiming a sea-cliff as younger than the sandy shore at its base. There is also good reason to think that if the country had been depressed in tertiary times sufficient to allow of the

[1] Mem. G. S. I., III., pt. 2, chap. III.

Fig. 1.

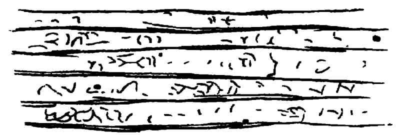

Fig. 2.

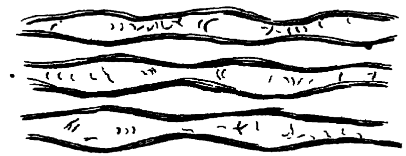

Fig. 3.

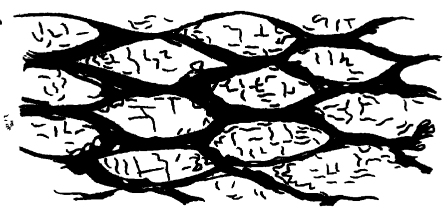

Fig. 4.

Fig. 5.

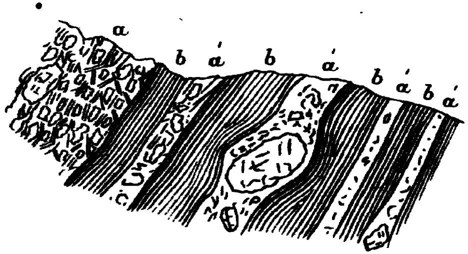

Fig. 6.

DIAGRAMS.

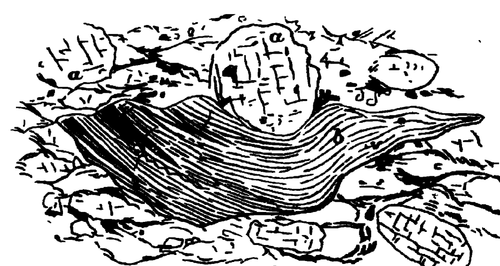

Fig. 7.

Aminullah.

formation of the gneissose granite where Kalogarhi now is, there would have been some phenomena of metamorphism exhibited by the tertiaries themselves, especially since in the Kotedwar glen they are only distant 5 or 6 miles from the intrusive boss of Kolagarhi.

On the whole, it would seem that Plutonic action first, followed by mechanical strain due to tangential pressure as the Himalaya continued and continue growing, must be considered the order in which the agents of change have acted on the Kalogarhi and Dudatoli areas. That this lateral pressure acting on slates and schists should bend them to its will, is not surprising; but we can also imagine that wherever they were stayed by ribs of massive granite, they would have strength to resist largely the contorting pressure, which would then spend itself producing re-arrangements of the particles and of the crystalline texture of the rocks, thus imprinting on them a foliated or semi-foliated character.

REFERENCES TO PLATE.

Fig. 1. Garnet in schist, shewing mica films folding round it.
„ 2. Gneissose granite, FOLIATED: *tabular*.
„ 3. Ditto ditto *lenticular-tabular*.
„ 4. Ditto SEMI-FOLIATED: "*augen*."
„ 5. Quartz schist shewing lenticular-tabular foliation a=pebble.
„ 6. Section at Marwara, near Kainur: a=gneissose granite mass. a'=thin bands of gneissose granite b=mica-schist.
„ 7. Inclusion of mica-schist (b) in gneissose granite (porphyritic "augen" near Kainur. a=porphyritic orthoclase crystal.

Preliminary Sketch of the Geology *of* Simla *and* Jutogh,[1] *by* R. D. OLDHAM, A.R.S.M., *Deputy Superintendent, Geological Survey of India.* (With a map.)

The geological structure of the Simla hill station, if regarded in detail, is one of extreme complexity of varying dips and innumerable faults, but on the large scale it is on the contrary simple to a degree, as may be seen on the accompanying map.

The oldest rocks are exposed along eastern and north-eastern limits of the map and all along the road to Mashobra; they consist of fine-grained micaceous grey slates with occasional quartzite bands, originally described by Mr. Medlicott as the infra-Blaini or Simla slates. On the spurs either side of Annandale the prevailing dip is south-west-by-south which further east bends round to west-south-west. Near the upper limit of these slates there are some bands of a very trap-like sandstone or grit which I have only seen on the spur between Annandale

[1] The observations on which this account is based were made during a brief stay in Simla while preparing to start into the interior: the main features will be found fairly correct, but the boundaries of the rock groups have in many cases been sketched in without having been followed in detail.

and the glen and again near Sanjaoli, though it would probably be found in a corresponding position elsewhere. When weathered it is impossible to tell this rock from a decomposed trap, and even the unweathered rock has a very trap-like appearance, but its detrital origin is shown by the presence of rugged scales of mica arranged parallel with the bedding.

At their upper limit these beds become impregnated with carbonaceous matter, and in consequence the colour becomes darker and the streak changes from pale grey to black. They are succeeded by a remarkable and important set of beds, called the Blini (since changed to Blaini) by Mr. Medlicott, from their occurrence in the valley of the Blaini stream hich flows westwards from Solon.

The group was described by Mr. Medlicott as consisting of a pure hard limestone, generally pink, composed of thin beds aggregating 15 to 20 feet thick, and a conglomerate consisting of a matrix of fine-grained slates through which pebbles of quartz or slate were scattered. As applied to the group in the Simla neighbourhood, this description must be amplified, for, underlying the limestone and "conglomerate," there come carbonaceous slates, which usually weather white on the bedding surfaces, and below these comes another "conglomerate," the whole being probably about 200 feet thick.

As this group is one of great interest and, owing to its marked characteristics, great importance, it will be well to clear the ground by explaining that what has been called a conglomerate in the foregoing passage is not a conglomerate at all in the usual acceptation of the term. The rock consists of a fine-grained matrix through which are scattered blocks of slate and quartzite, as a rule angular or sub-angular, in some cases containing 8 or 10 cubic feet of stone. It is evident that a current sufficiently violent to move these blocks would have swept away the fine silt in which they were imbedded, while, *per contra*, any current sluggish enough to allow of the deposition of this silt would be impotent to move the small pebbles, to say nothing of the larger blocks which the now indurated silt encloses. The only possible explanation is that these fragments were dropped into a comparatively tranquil sea in which the silt was being gradually deposited, but there are only three known agencies by which this could have been affected, *viz.*, volcanoes, floating trees, or floating ice.

The rock in some respects resembles a volcanic breccia, and the resemblance is occasionally far more marked than appears in the Simla rock, but the steadiness with which the rock preserves its character over large areas, the frequent occurrence of well-rounded pebbles, the comparative absence of actually angular fragments, and more especially the absence of associated lavas or volcanic ashes, tell against this hypothesis. Floating timber is known to transport fragments of rock often of considerable size, but it is difficult to imagine how the enormous number of stones found in the Blaini boulder slate could have been thus transported, nor why the boulders should be confined to certain well-defined horizons; it would be strange too if out of the vast number of trees that would be required to transport all the blocks found in the Blaini group, all escaped fossilization, and the absence of carbonaceous matter from the boulder beds is very marked when they are compared with the associated slates.

The only hypothesis that remains is that of floating ice, which presents no difficul-

ties: floating ice is as capable of transporting waterworn pebbles as angular fragments without any limit of size; it melts away and leaves no trace beyond the fragments it may have carried with it, and, though the exact causes are not satisfactorily determined, it is a known fact that icebergs have formerly floated where none are now to be seen, and that regions now covered with perpetual snow and ice were once free from both. There is, consequently, no difficulty in accounting for the restriction of the transported blocks to certain definite horizons. Besides being the only hypothesis which does not land us in a difficulty there is a certain amount of corroborative evidence, for in 1884 Mr. C. S. Middlemiss discovered, in the Blaini group of the Naira (Neweli) valley in Eastern Sirmur, a pebble which was scratched in a manner very similar to that which is due to the action of glaciers, and I have myself seen in the neighbourbood of Simla several fragments which shew the same in a more or less obscure manner: in particular I may mention one block situated on the spur between Chadwick's falls and the glen which measures 4′ × 2′ × 1′ exposed; on one face it is smoothed and scored in a manner that can hardly but be due to glacial action. Taking everything into consideration we may, therefore, decide that when the Blaini group was being deposited, the spot now occupied by Simla was a sea on whose surface icebergs floated, melted, and dropped the stones, which they carried, on their surface or imbedded in their substance.

Returning now to the description of the rocks, the Blaini group, as defined on the accompanying map, consists at the base of a boulder slate; above this come carbonaceous slates which differ from those above and below by the manner in which they turn white on the weathered surfaces. The same feature is occasionally seen in the other carbonaceous beds, but in this particular band it is, so far as I know, universal. Above this again comes the original Blaini group of Mr. Medlicott. At the base it consists of a dark red slate which passes upwards into grey, occasionally blackish and carbonaceous, slate through which boulders are scattered, and above that there comes a thin-bedded pink limestone. It is this group of beds, not more than 60 feet thick in all, that is most easily traced (many of the exposures having already been recorded by Colonel McMahon[1]) and has been followed more completely by me than any other boundary. It enters the map in a side ravine flowing into the main stream below the Chadwick falls and can be traced over the spur into the Chadwick ravine; up the east side of this ravine it cannot be traced continuously, being hidden by surface debris; it may be cut by a small fault here, but this must be of later small throw, for the beds reappear in their proper position on the crest of the spur; they can be traced down into the glen, being hidden near the top and again near the bottom by soil cap, but, for the greater part of the way, can be traced practically continuously and closely follow one of the native footpaths. In the bed of the stream flowing through the glen the limestone is seen and is cut by a small fault which brings it into immediate contact with the red slates. It is again seen on the ascent from the glen and can be traced over the spur separating the glen from Annandale and runs down to where the road round this spur passes the spring which supplies the village of Gowai (of the map) with water. Here the limestone disappears, being apparently cut off by a fault; it cannot be traced across the Annandale valley owing to the rocks

[1] Records, G. S. I., X.

being hidden by sub-recent stream deposits, but may be seen in the stream bed and on the road which leads up the spur. East of Annandale it suddenly reappears, being evidently brought up by a fault. As the road rounds the end of the spur to turn back on itself, the red slates appear overlaid by the boulder bed and the limestone, here only represented by a few weathered blocks, the greater portion having apparently been removed by solution. The limestone and conglomerate can be traced with fair continuity over this spur along its western side, where again a native footpath follows it very closely into the ravines below the ridge. I did not follow it here, but it reappears below the ridge and can be traced up, passing below the Lakar Bazaar, on to the road round the north side of Jacko, where it crosses a spur and appears to run down into the valley west of Snowdon, but the ground is so covered that I was not able to trace it. Going along the North Jacko road the Blaini comes in once more, rather suddenly, as if brought up by a small fault, and runs past Snowdon, where there is a very characteristic exposure of the conglomerate just outside the guard-house. The limestone appears to run down under shady dell, but where not built on the ground is so covered with surface debris or spoil that has been tipped in levelling ground for roads or buildings, that it is impossible to follow the beds. However this may be, the Blaini is not again seen till just beyond the ravine where the upper and lower roads round Jacko separate. The beds are here brought up by a fault which shows itself as a line of springs. From here the Blaini can be traced across the upper road and up the spur to below the summer house in the grounds of Holly oak; here it appears to be again cut by a fault and is next seen just above where the road turns round the end of Jacko; there is only a small patch here, the beds cannot be traced in either direction, nor do they shew on either of the roads along the south side of Jacko. The limestone and conglomerate may however be found in the ravine below the Simla Rifle Club's range, west of and about level with the village of Sangati (Sanguti). I did not see it again till just above Sháman (Chaman) village where it can be traced practically continuously past Balahi, beyond which the limestone has been quarried. It runs down the west side of the Chota Chelsea spur and is seen near the Dhobi ghât below Chota Simla: hence it can be traced at intervals along the east slopes of the continuation of the Chota Simla spur till it runs out of the limits of the map.

It is noteworthy that the limestone is always well seen on the hill sides facing southwards, while on the northern face, which is covered with forest, the outcrop is always thin and often wanting. It is a known fact that the air contained in the interstices of the soil of a forest contains a larger proportion of carbonic acid gas than that of open ground; the water which percolates this soil would consequently become more impregnated with the gas and would be a more active solvent of the limestone than that which percolated the soil of the southern slopes. To this fact seems attributable the thinness or absence of outcrops of limestone on the northern slopes.

The lower conglomerate I did not trace with the same continuity as the upper one. It is seen in the Chadwick stream and again on the spur separating that from the glen. I next saw it where the road from the glen to Annandale passes over the spur, and it can be traced round the spur east of Annandale. On the Elysium spur

it crops out where the path leads up to the Elysium Hotel and again immediately above the house called Sylvan Hall; it is seen below Snowdon and again in the stream east of the forest, but whence it runs round towards the Mayo Institute. It appears on the Mall just above this place and can be seen running at first along, then below, the Mall till it crosses the ridge where the lower road rounds the end of Jacko. Southwards from here I did not trace it, but have no doubt that it continues in the same position relative to the upper conglomerate, and have consequently drawn it as doing so.

Above the Blaini comes a band of slates or schistose slates characterised by being more or less impregnated with carbonaceous matter: these were regarded by Mr. Medlicott as the same as some very similar beds called by him infra-krol, owing to their occurrence beneath the limestone of the Krol Mountain, which rises above Solon. But as it is not certain whether these or some similar beds seen at Jutogh represent the beds of the Krol Mountain, it will be better to describe them as the lower or Jacko carbonaceous slates. The upper limit is very indefinite, being only determinable by the presence or absence of the carbonaceous ingredient, and as this appears to be very capriciously distributed, it is probable that beds of the same age may have been mapped in one place as belonging to this and in another to the next group. Owing to the indefiniteness of the boundary I did not pay much attention to it, and as drawn it is for the most part conjectural; but, apart from some such explanation as is given above, or faults which I have not detected, it is impossible to account for some peculiarities in the boundary, which do not appear to depend on the dip of the beds and contour of the ground.

The essential characteristic of this rock is the presence of an appreciable proportion of carbonaceous matter. Occasionally, more especially where the rock is crushed, this is very conspicuous, gives the rock a sooty appearance, and produces a blackness of the hill sides which can be recognized from a distance as at Chadwick's falls and on the road along the south face of Jacko between the convent and Sanjaoli Bazar. Where the carbonaceous matter is in so large a proportion, the rock often assumes bright colours on its surface due to the efflorescence of various soluble salts produced by the decomposition of some of the mineral constituents of the rock. As a rule however the carbonaceous element does not make itself so conspicuous and is only recognizable by the black colour and more especially the black streak of the slate. It is also noteworthy that where these beds are exposed on a ridge and have been much weathered, the carbonaceous element appears in many cases to have been almost if not entirely removed.

The Jacko carbonaceous slates follow the Blaini very closely, except that they run over the ridge and down the Combermere ravine where they extend to near the Brewery, but are ultimately covered up by the general south-south-west dip of the beds: immediately below the first waterfall is some dark limestone which may belong to these beds.

Above these carbonaceous slates, which are about 300 feet thick, there comes a thousand feet or so of quartzites and schists for which I cannot do better than adopt Mr. Medlicott's name of Boileauganj quartzites. It is these beds that are seen for many miles along the cartroad, along the whole of the Mall, except near the bazaar and the road to Jutogh, as well as on all the southern and western spurs. The

greater bulk of the beds is quartzite, usually somewhat impure and schistose, but there is no small proportion of what must be called schist, occasionally garnetiferous. On the Boileauganj hill it has frequently a peculiar corrugated structure consisting of small rolls or larger rolls and giving the surfaces along which it breaks off an appearance which bears a distant resemblance to a bundle of sticks; hence the structure is called *bacillary*. These beds present very little of interest, so I shall pass on to the next group.

The upper or Jutogh carbonaceous slates and limestones are the newest rocks within the limits of the Simla station. They occupy three isolated patches—one, the largest, on the Jutogh hill, one on Prospect hill, and one small patch on the spur intermediate between these two. Like the Jacko beds, these are characterised by the presence of carbonaceous matter, but they differ in the prevalence of limestone: in the Jacko beds I have only seen limestone in one place, on the spur east of Annandale, while large quantities of limestone have been quarried, both for burning and as a building stone, from the Prospect and Jutogh hills. At Jutogh there appear to be three distinct bands of limestone, separated by schists and quartzite, but on Prospect hill only the lowest band seems to be left; this is overlaid by thin-bedded quartzite, and the hill is capped by a peculiar garnetiferous hornblende rock. Occasionally the garnets are absent, and it forms an intensely tough almost black rock, but usually a greater or smaller proportion of garnets are to be seen, which in places form fully a quarter of the substance of the rock: they occur for the most part as crystals of all sizes up to half an inch across, but where abundant there are also veins of garnet penetrating the rock. It is difficult to account for this rock; it has not yet been examined in detail, but the most probable explanation would be that it is an altered impure volcanic ash; if so, the absence of any similar or related rocks either on this hill or in a corresponding position at Jutogh is peculiar: the rock may be intrusive, but to the naked eye it has not that appearance.

The most marked feature in the geology of Simla and one that has been remarked on before now is the metamorphism of the higher beds accompanied by the absence of metamorphism in the lower beds. The grey Simla slates, though indurated, shew no signs of what could be called metamorphism, while on Jacko and the Boileauganj hill there are well-developed mica schists, and the limestones of Prospect hill and Jutogh are crystalline, and in the latter case contain well-developed crystals of graphite. [The rocks all down the southern slopes of the Simla hill shew more signs of metamorphism than the Simla slates, but less than the similar rocks of the ridge.] To a certain extent this is due to selective metamorphism, that is to say, the same, or a less, degree of heating has, owing to difference of composition, produced greater change than in the Simla slates, but this hardly seems enough to account for all the facts. In an unpublished paper by Mr. Medlicott on the geology of the Punjab, intended to be published in the Punjab Gazetteer, it is suggested that the heat may have been applied from above by the intrusion of a sheet of granite, since removed by denudation. This hypothesis has a *primâ facie* probability, for such sheets of granite have been observed in other parts of the Himalayas, and there is the remnant of one left on the very top of Hattu, where a very little more denudation would remove all trace of it, as Mr. Medlicott

supposed it to have done at Jacko. The hypothesis is however not free from difficulty, for there is no known outcrop of granite in the neighbourhood of Simla, and all round Jacko the rocks do not shew that metamorphism one would expect them to shew had a sheet of granite been pushed over them and retained its heat sufficiently to account for the metamorphism of Jacko. A third hypothesis would be that the metamorphism was due to a core of granite or other igneous rock having been intruded into the rocks but not yet laid bare by denudation. This is not impossible, for the porphyritic granite of the Himalayas appears usually to have eaten its way into the rocks by a process of fusion or solution by which the rock became incorporated with and replaced by the porphyritic granite. This is not the place to give the detailed observations on which the conclusion depends; suffice it to say that there are many facts which render it the only explanation possible in the case of the Chor and other intrusive masses, and granted this conclusion it is easy to see that there might be a great core of granite occupying the centre of the Simla hill without betraying itself either by actual outcrop or any conspicuous disturbance of the beds. Still the hypothesis is an improbable one.

Among these conflicting hypotheses it is impossible to pick out the true one, and probably the safest course will be to fall back on the first as a provisional conclusion. In any case, I do not doubt that selective metamorphism has had great influence, for I have noticed, in other parts of the Himalayas, that the rocks of the same age as those of the Simla hill are especially prone to metamorphism. Still this alone will not explain how the beds on the ridge have come to be distinctly more metamorphosed than those in the valley to the south of Simla, though they must originally have had practically the same composition.

The surface geology of Simla is of considerable difficulty, and I have not had time to make any but the most superficial observations of it. Almost everywhere the hillsides are covered by a soil cap consisting of a mixture of fragments derived from the underlying rock and of soil formed by the further decomposition of these fragments. This soil cap is in a state of progression down the slopes; part of this movement is cataclysmal in its nature, and takes place in the form of what are known as landslips, where a portion of the soil cap is suddenly carried a greater or less distance down the hillside and there rearranged; but besides this there is a slow though sure creep of the soil cap down the hill, which to a certain degree affects even what might be called live rock. This movement of the slightly disintegrated rock can be seen in almost every road-cutting. The rocks are all cut by more or less vertical joint planes, known as master joints, along which the rock splits off, as may be seen in any quarry. In the road-cuttings, however, it is seldom that these master joints shew a smooth face; as a rule, there are a series of smooth surfaces of various size, the upper projecting more or less beyond the lower where the rock has shifted along a bedding, or slightly inclined joint, surface. Where the rock has not been much split up, it is easy to see that these surfaces were originally continuous and have been broken only by the shifting of one part of the rock over the other without their evident relationship to each other having been obscured; but, by a gradual repetition of this process, the joint planes become completely obscured, and the rock gradually passes into an irregular aggregation of fragments constituting the typical soil cap.

It is to this gradual movement of the rock without any great breaking up, as well as to a cause presently to be mentioned, that the dip of the rocks appears to be always into the hill, and even into the minor spurs. It is a well known fact that, on the whole, hills are formed by synclinals and valleys along anticlinals, and the Himalayas are no exception to this rule, but it does not hold good to anything like the extent a casual observer might conclude from the fact that almost every dip he could observe pointed more or less directly into the hill, whatever the actual direction might be. This is in part due to the natural tendency of the broad, flat, rock fragments to arrange themselves at right angles to the direction in which they are slowly moving. In this way a weathered rock may be seen to dip into the hillside, though the true dip of the unweathered rock may be very different to that observed, and consequently it is never safe to trust to a dip observed in weathered rocks.

But even dips observed in solid rock that shews no signs of weathering and shews the true dip of that small portion of the rock, may give a very false idea of the true dip of the beds as a whole. Often along a hillside outcrops of rock are scattered, and all indicate a dip into the hill, though the actual direction will vary with the direction of the slope, while the form of the geological boundaries may shew that the general dip is fairly steady in direction and amount. The explanation of this may be seen in any deep cutting or stream bed: here the beds will be twisted about and contorted on the small scale to such an extent that whatever may be the general dip it will be easy to find some places that will give a dip in any selected direction. Now if this same rock is exposed on a hillside, in all places where the dip is down the slope or neutral (*i.e.*, at right angles to the direction of the slope), the rock will more readily weather into the soil cap than in those places where, owing to the dip being into the hillside, the fragments are able to give each other a more efficient support. In consequence of this we may naturally expect that it will generally be where the dip happens to be into the hill that the rock will be able to resist denudation so as to stand out from the general slope of the soil cap. In other words, the apparent dip into the hillside may be due to the direction of the slope and not the direction of the slope due to the dip. The Simla hill affords a very good instance of this. The general structure of the hill, as shown by the boundaries, is a very shallow synclinal whose axis bears north-east and south-west and is elevated to the north-east. In consequence of this the general dip is south-south-west or west-south-west, but, in spite of the assistance rendered by the numerous road-cuttings, the general impression left is that the rocks will everywhere be found dipping into the hill, whatever that direction may be. A careful consideration of the facts has, however, convinced me that this is only because it is to a very large degree only those dips which happen to be in that direction, which have a chance of being observed, the others being almost all obscured by soil cap.

In the valleys round Simla there are some sub-recent river gravels; they are not extensive in the area included in the map, but there is a large stretch of them extending beyond the limit of the map, in the stream which drains the southern slope of the ridge between Prospect hill and Jutogh. On the eastern side of the stream which forms the eastern boundary of the map, south from Sanjaoli, the same beds

are seen not in very great quantity, but shewing their nature very well: they may also be seen in any of the khuds, and the road along which the sewer is laid down to the waterfall shews very good sections of them. They are seen to consist of a *melange* of fragments all more or less angular and varying from some feet across to fine gravel, in fact showing many of the characteristics often considered peculiar to morraines. There is not however any reason to consider them of glacier origin, as they invariably show distinct stratification, a structure which, though not always wanting, is more conspicuous by its absence than by its presence in a true morraine. Stratification is essentially the mark of flowing water, and there can be no doubt that these deposits were formed by streams ; the angular nature of the debris being easily explained by the short distance it has travelled, while the mixture of large and small fragments is due to the steepness of the slope of deposition and the varying quantity of water which would flow at different times.

A point to be noticed is that these gravels extend in many cases right down to the bottom of the valleys, showing that these latter had been excavated to their present depth and then filled up by a deposit which is now being removed.

In the valley which leads southwards from Sanjaoli there is sufficient of the deposits left to form some idea of the original form of the surface which is now being destroyed. In the main valley there was a long sloping tract, the slope of this being somewhat steeper than that of the present stream bed. This "bottom" sent tongues up the small side valleys, the surface of these tongues having a slope steeper than that of the bottom and increasing up stream till at the summit it becomes 30°, as steep a slope as ordinary debris will lie at. This gradual steepening of the slope so as to form a concave surface is very conspicuous in the side ravines flowing from the east into the stream which flows south from Sanjaoli and is best seen from either of the roads round Jacko, as Sanjaoli is approached.

The explanation of the curve is not difficult. The slope is formed by debris deposited by the stream when its velocity is reduced below the limit at which it can transport the debris; but a large volume of water will acquire a given velocity on a smaller slope than a small volume; consequently, as the volume of the stream increases, the limit of velocity at which the debris must be deposited is reached on a gentler slope, and therefore the slope of the surface of the deposit diminishes as the stream increases in volume, *i.e.*, down stream. It is in the small side streams that the increase of volume is most rapid, relative to the volume of the stream, and consequently there that the curvature of the surface of deposit is most conspicuous, and in these side streams the effect enhanced by the fact that the large fragments are the first to be deposited, while the smaller fragments which are carried on require a less velocity and consequently a smaller slope to allow of their transport.

In trying to account for these high level gravels the most obvious explanation would be to suppose a change of level which caused the stream that had originally been eroding its valley to commence depositing debris in it, and then another change of level by which it was once more set to work at excavating. But similar deposits may be found in almost every valley throughout the Himalayas, and where not observable it is more probable that they have been entirely removed than that they never existed. It is impossible to suppose to suppose that every valley had its own special set of movements, and no general movement will account for all the

deposits, nor for the greater steepness of the surface of the old gravels than that of the recent stream beds and gravels.

When the gravels were being deposited the streams which flowed over their surface must have had a lower maximum velocity than the present stream acquires on a smaller slope; its maximum volume must therefore have been less or it must have been so loaded with debris as to be spread out in a shallow sheet and prevented from acquiring the velocity it otherwise would have done. In other words, the conditions then differed from those of the present day in that either (1) the rainfall was less or less unevenly distributed through the year, or (2) the disintegration of the rock was greater than what now takes place.

Taking the first of these, it might be supposed that the cutting down of the stream beds was due to the clearing of the hillsides by human agency. It is known that clearing the forest diminishes rainfall, but makes what does fall more unevenly distributed in time; moreover this effect is exaggerated by the increased rapidity with which the water flows off the hillsides. It cannot however be to any such cause that the observed facts are due, for they are just as conspicuous in the streams draining from the forest clad northern slopes of the hills as in those which flow from the bare grassy slopes with a southern aspect. Besides this as far as can be judged from the appearance of the stream beds the increased disintegration caused by the removal of the protecting forests has more than counterbalanced the increased volume of water at the maximum discharge, and in nearly every case of streams draining the southern slopes it will be found that, not far from their sources, deposition is outbalancing erosion and the stream has become on the whole a depositing rather than an eroding agent, so far as its lower reaches are concerned.

Apart from the clearance of forests we know of no change in the rainfall which would account for the alternation of conditions shewn by the river gravels, but we do know of a cause which would greatly increase the rate at which the rocks would be disintegrated, and at the same time would probably have some effect in diminishing the rainfall. There are many reasons, which need not be entered into here, for believing that the glacial epoch was felt in India as in Europe. There is no certainty as to the extent to which the snow line was lowered, but there is good reason for believing that in places glaciers descended to 4,000 feet, if not lower. If we only suppose the snow line to have been depressed 5,000 feet, the whole of the Simla hill would have been cleared of forest, and disintegration proportionately increased; at the same time this great accumulation of snow could not but have had some effect in diminishing if not abolishing the monsoon rains, but as this may have been counterbalanced by the supply of water derived from the melting of the snow in summer, we cannot be sure, though it is very probable, that the maximum volume of flood was less than now.

The hypothesis that the formation of the gravels dates from the glacial epoch has the merit of explaining all the facts and of not conflicting with any other known facts. It allows of a mild climate during which the valleys were excavated to their present depths, then a period when disintegration was increased, both directly by the increased cold and indirectly by depriving the hillsides of their protecting forest; during this period possibly the actual volume, and certainly the volume of the streams relative to the burden cast on to them decreased, and in consequence

deposition commenced. Then came an amelioration of climate during which disintegration gradually decreased both directly and indirectly, while the maximum volume of the stream increased, if not absolutely at any rate proportionately to the load it had to carry, and in consequence erosion once more set in, which has continued to the present day.

This filling of the valleys has not caused any considerable hydrographical change in the area under consideration, but the two waterfalls in the Combermere glen are both due to a small diversion of the stream. In both cases the old river bed ran west of the present one, but is now filled up with gravel, the stream when it began once more to erode choosing a slightly different channel to that it had originally occupied cut down to a saddle on the buried spur from which it could not work down to the old course; at the same time the more rapid removal of the soft gravels below the spur caused those spreads of gravel with a rapid drop over a rocky barrier at their lower end which are now known as the first and second waterfalls.

The economic geology of the Simla hill is very limited: building stone is naturally in abundance and of a quality good enough for rubble masonry; where dressed stone is required the limestone of Prospect hill or Jutogh is used.

A certain amount of pottery clay is found on the slopes, some of the spurs running north from Simla: it appears to be confined to the neighbourhood of the carbonaceous slates and to be largely composed of the insoluble residue of the limestones associated with them. A large deposit existed on the north slope of Jutogh, but has been almost entirely removed to make bricks and tiles for the new offices in Simla. Another large deposit appears to exist on the Summer hill spur beyond where the road rounds its northern end, but at present it is only dug to make a few gurras, flower pots, &c. Another place where clay is found and worked is on the eastern slopes of the spur east of Annandale. Here there are several potters' houses dotted along the hillside.

The water-supply of Simla has for many years been a source of difficulty; and water is now brought in by pipes from the Mahasu ridge.

Note on the "Lalitpur" Meteorite, *by* F. R. MALLET, *Superintendent, Geological Survey of India.*

We have received from Colonel J. Liston, Deputy Commissioner of the Lalitpur district, in the North-West Provinces, several pieces of a meteorite which fell in the district during the present year, together with such information as could be collected about the fall. It appears that the meteorite fell at 10-30 A.M. on the 7th April, on the boundary line between the villages of Jharaota and Nyagong, in parganna Maraura; approximately, therefore, in latitude 24° 27′, longitude 78° 39′.

Two boys, who saw it fall, said they were startled by a report like that of a gun, looked up, and saw the stone just before it reached the earth. After it fell "a grumbling, like thunder, went on for some time." The meteorite fell on a stone and was broken into pieces: the boys did not go near them for some time from fear: when they did the fragments were cold. The direction of the fall is said to have been from west to east.

"The noise was heard in, and reported from, two places at a distance from the spot where the meteorite fell. Mr. Sturt, Assistant Commissioner, wrote to me from Mahroni, where he was then encamped, that, at 10-30 A.M. on the 7th April, he heard a sound like thunder, went outside his tent to find a clear sky and no signs of a storm, and found the people about wondering what the noise meant. Mahroni is 9 miles 2½ furlongs north-east of the spot where the meteorite fell. The police officer of Dudhaie, 10 miles 2 furlongs due west, reported that at the same time (he says 10 A.M. but had no watch) he heard a sound like a heavy cart going over a rough road; went outside his station to see what the matter was, and could see nothing. He reports the sky to have been perfectly clear at the time."

The Deputy Commissioner remarked that as the meteorite fell on a stone the fragments were scattered and many have probably not been found. Seven were secured by him, one of which subsequently broke in two, making eight in all. These have been sent to the Geological Museum in Calcutta: they respectively weigh—

A.	128·04	grammes
B.	82·23	"
C.	56·40	"
D.	38·21	"
E.	28·77	"
F.	22·32	"
G.	13·78	"
H.	2·09	"
TOTAL	371·84	(about 13 ounces avoirdupois).

The fact that there are but two pairs that admit of being joined together shows that, as surmised by Colonel Liston, many fragments are wanting. Those sent have the usual black crust on the original exterior, and are composed of a fine-grained, grayish-white stony mass, through which a small proportion of substance with metallic lustre is disseminated, chiefly in very thin seams, but partly in minute grains. The examination of a few milligrammes of this showed that riccoliferous iron is the main constituent, but troilite and schreibersite are both, apparently, present also. The specific gravity of the largest fragment of the meteorite is 3·546.

ERRATA.

Records, Geological Survey of India, Vol. XX, Part 3.

Page 121, line	8 from top,	for *thirty* read *thirty-three*.	
„ 122, „	15	„	after *canals* add *Jour. Roy. As. Soc: Lond. XX*, 326, 1863.
„ 123, line	3	„	for *Tovla* read *Toula*.
„ 123, bottom	line,	„	*first* „ *this*.
„ 136, line	2 from top,	„	*Bandin* „ *Bandni*.
„ 137, „	25	„	„ *Matkori* „ *Malkori*.
„ 137, „	42	„	„ *slates* „ *states*.
„ 144, „	5	„	„ *rugged* „ *ragged*.
„ 145, „	35	„	erase the word *later* between *of* and *small*.
„ 147, „	4	„	for *forest, but* read *forest hut*.
„ 148, „	5	„	„ *or* read *on*, and erase the word *and*.
„ 148, lines 36 &	38	„	erase brackets.
„ 150, line	15	„	for *dips* read *a dip*.
„ 153, „	20	„	„ *slopes, some*, read *slopes of some*.
„ 154, „	3 from bottom,	for *riccoliferous* read *nickeliferous*.	

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] **1887.** **[November.**

Note on some points in Himalayan Geology, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

The observations on which the following remarks are based were made partly in company with my colleague Mr. C. S. Middlemiss, partly by myself alone during the spring of 1884. During a brief tour in the lower Himalayas my attention was directed to an attempt to elucidate some doubtful points in, and as far as possible to complete, the sequence of sedimentary formations in the lower Himalayas. As a consequence very little detailed mapping was done, and that only where the structure of the hills appeared to be simple enough to allow of some definite conclusion being arrived at as to the superposition and relation of the rock groups. Nothing was published at the time, as the conclusions arrived at were for the most part provisional and liable to alteration. Since then there has been no opportunity of correcting or amplifying them, but on consideration there seem to be some points of sufficient interest and importance to warrant publication.

The limestone of the Naira valley.—In the valley of the Naira river (Neweli of map) in eastern Sirmúr a massive limestone is exposed, some of the beds having a strong sulphurous odour, while near the base are some oolitic bands. As regards lithological appearance, it does not differ markedly from either the Krol or Deoban limestones, it extends on either side of the valley and forms the Juin peak on the north, and the hill which rises above Dugána on the south. At the Juin station it is cut off by a combination of a uniclinal fold and faulting; to the south it is cut off by denudation. On the summit of the peak above Dugána there is a limestone conglomerate, cemented by calcareous mud, which resembles some of the conglomerates in the Mandháli series on the Deoban ridge. This fact, combined with the occurrence of carbonaceous slates in the upper part of the Naira valley, where they appear to overlie the limestone, led me at the time to regard the latter as of Deoban, rather than Krol age.[1] Subsequent consideration has, however, led me to doubt this

[1] I shall show later on that the two limestones are distinct in age.

conclusion, the superposition of the carbonaceous slates may well be due to disturbance, for the beds are very much disturbed in the upper Naira valley, while the limestone conglomerate is a rock which might naturally be expected to occur as the bottom bed of a formation resting unconformably on massive limestone.

The Blaini group in the Naira and Bangál valleys.—Below the limestone there come grey slates in which the Blaini limestone and boulder bed occur; it was traced from the crest of the ridge south of the Náira valley into the Bangál valley, being much cut up by faults; it is carried up one side and down the other of the ridge which separates these two valleys by a series of step faults, which are especially marked on the south side of the ridge. These faults run in the direction of the boundary of the massive limestone on the Juin hill, and in that rock seem to die out as faults, and become converted into a uniclinal fold.

The group is of the same type as that first described in the Blaini valley, consisting of a single band of pink limestone and conglomerate, the latter containing many fragments of volcanic rock derived from the volcanic series which will presently be mentioned. In the bed of the stream which flows east of the village of Bombhil, close to its junction with the Naira there is an exposure of the boulder bed which distinctly marks its mode of origin. The matrix is laminated and the laminæ are seen to be bent down under, and to arch over, the larger included fragments, showing that these must have been dropped into a tranquil sea in which the fine silt of the matrix was being deposited.

It is not necessary to recapitulate here the reasons why I regard the boulders as having been dropped by floating ice, but I may mention that where the boulder bed crosses the Naira valley we discovered a pebble (now in the museum) showing striations similar to those usually ascribed to glacier action. It is, however, necessary to notice the extraordinary similitude to a volcanic breccia exhibited by the Blaini "conglomerate" on the Juin ridge: not only are the included fragments mostly of volcanic rock, but the matrix itself very strongly resembles an impure volcanic ash. It is not natural to suppose that this rock should here be of volcanic origin, while elsewhere, and in general, such an origin can be shown to be untenable, so we must look to some other cause for the resemblance. This I imagine to be the same as explains the other features presented by the rock, *viz.*, a severe climate. Under the climatic conditions which now prevail even at an altitude of six or seven thousand feet, the volcanic beds disintegrate, principally by the decomposition of their constituent minerals, but it is conceivable that, under a climate severe enough to produce floating ice at the sea level, the disintegration of the rock would be more rapid than the decomposition of its constituent minerals; in this case it would be difficult to distinguish the sandy material so produced from the ash directly produced by a volcanic eruption. I know of no observations confirmatory of this hypothesis or the reverse, but it seems a possible one, and at any rate does not conflict with conclusions arrived at on independent grounds.

The volcanic beds and "lower Chakrata" quartzites of the Bangál and Naira valleys.—Under the Blaini beds, but separated from them by slates, comes a series of volcanic beds, consisting of felsitic lavas and ashes, underlaid conformably by purplish red and mottled quartzites, with interbedded schistose slates. This series of beds I have no hesitation in correlating with what I have described as the Lower Chak-

ratas, and overlying volcanic beds of Jaunsar, as they resemble each other, not only in lithological character, but in the order of superposition of the beds.

Regarding this, the most important fact to be noticed is that part, at least, of the volcanic beds is of subaërial origin. In proof of this statement, I appeal to a specimen, preserved in the Imperial Museum at Calcutta, where portions of two distinct lava flows are seen to include between them a string of well-rounded, water-worn pebbles. Were these only of lava, it would not indicate more than an isolated volcanic island, which need not have been raised more than enough to bring its summit within reach of the breakers, but the majority of the pebbles are of vein quartz, which must have been derived from some land surface of non-volcanic rocks.

On the north side of the Bangál valley below the village of Lána there occurs, far below the volcanics, a bed which, like the Blaini "conglomerate," can hardly but be of glacial origin. It consists of rounded, waterworn boulders of quartzite, imbedded in a fine grained, red coloured, subschistose matrix. This rock was not seen *in situ*, so there is some doubt attaching to its geological position, but it occurs in large fragments just where a continuously descending section of the red quartzites and volcanic beds is faulted against the Deoban limestone. It is important to note that this is not a volcanic bed; it is separated from the volcanics by the "Lower Chakratas" and a considerable thickness of schistose slates that underlie them; and the well-rounded condition of the boulders, which range to over a foot in diameter, shows that they have been waterworn.

In northern Jaunsar I have seen a very similar bed at about the same horizon; its position is represented by the southernmost of the two blue patches in Jaunsar on the map illustrating Col. McMahon's paper on the Blaini groups and central gneiss of the Simla district.[1]

Relation of the Blaini beds to underlying rocks.—On the north side of the Bangál valley the volcanic series is overlaid by about 1,000 ft. of subschistose grey slates. On the south side there are at most a few hundred feet of slates between the Blaini and the volcanic beds, and these appear to belong rather to the Blaini than the volcanics. On the crest of the Juin ridge the volcanics do not seem to have thinned out appreciably, but down the slope into the Naira the thickness of them lying between the purple quartzites and the Blaini slates diminishes, till in the Naira valley the volcanics have disappeared entirely.

It is possible that this may be due to faulting, but the recognizable faults are almost all dip-faults, which would not affect the apparent thickness of strata between the purple quartzites and the Blaini group, while the beds lie too flat for their appearance to be due to a squeezing out of the rocks in consequence of contortion; nor, were such to take place, would one expect the volcanics to be squeezed out rather than the overlying slates.

It might be supposed that the thinning out of the volcanics represented their original limit of extension, but that is hardly probable, for a band of limestone is inter-stratified with them throughout Jaunsar, while, as I have already shown, they are of subaërial origin in Bangál valley. It is reasonable therefore to suppose that this locality marks the neighbourhood of a focus of eruption, and a sudden thinning out in its neighbourhood is not what would be expected.

[1] Records, G. S. I., X, p. 222.

A more natural explanation is to regard the thinning out of the volcanics and overlying slates as due to their removal by denudation, previous to the deposition of the Blaini. This view derives some support from the presence in the Blaini boulder bed of angular fragments of volcanic ash, which must have been indurated and converted into solid rock previous to their transport to the locality in which they are now found.

Termination of the ridge between the Naira and Bangál valleys.—Along the termination of this ridge, where it slopes down to the Tons, and in the Naira valley, there is exposed a grey slate series containing a band of blue limestone about 300 feet thick. These resemble the slates and interbedded limestone of Southern Jaunsar which were described by me as "Upper Chakratas." West of the Tons they appear to pass under the "Lower Chakratas," and the section upwards from the latter is a normal one. This apparent reversal may be due to disturbance, but there is every possibility that the section in Jaunsar on which I based my conclusion was inverted. The question of which of the two, the slates and limestone or the red quartzites, is the newer, remains to be decided by further survey.

Unconformity at the base of the infra-Krols in the Valley of the Minas gádh (Suinj R. of map).—The whole northern side of this valley appears to consist of limestones; possibly near the top some other series may come in, for I did not examine the hillside, but certainly the greater part of the northern side of the valley, near the Tons, is composed of a limestone series, which I see no reason to doubt is the same as that of the Deoban hill. The limestone extends south of the stream and can be seen faulted against the purple quartzites of the "Lower Chakrata" series. At the head of the valley both limestone and quartzites are overlaid by a band of black carbonaceous slates and limestones, which is also seen in the Gerwáni hill, resting on the grey slates that overlie the volcanics. This carbonaceous series can be very distinctly traced along the hillside, and, though it appears to be faulted in the Minas valley, does not seem to be cut by the fault which separates the limestone and quartzite series lower down, at any rate not to the same degree. This would point to the boundary fault being of great age, and to a complete removal of the Deoban limestone south of it previous to the deposition of the black carbonaceous slates, and consequently to a great unconformity at their base. These black carbonaceous slates can be traced into continuity with similar beds in the Chepal valley, where there can be little doubt that they represent the infra-Krols of the Simla region.

The Mandhâli beds of the Chor and Chepal.—On the eastern side of the Chor mountain there are several exposures of a boulder bed, very similar to the Blaini conglomerate in physical characters, but without the characteristic associated limestone. The most southerly exposure is on the north side of the Minas valley a little below the hamlet of Dím (Demi). The boulder beds are here interstratified with blue limestone, a feature also noticed in the Mandhális of Jaunsar, and lie between the massive, presumably Deoban, limestone and the carbonaceous slates. This "conglomerate" is not continuous in this position, as it is wanting near the village of Deothali (Thotali), but it is present on the Cheti (Baiti) ridge.

Between this and Chepal the rocks are too disturbed for their structure to be determinable in a rapid survey, but east of Chepal the boulder beds recur in the

same position as further south, *viz.*, between the massive limestone and carbonaceous slates. The beds are a good deal cut up by faults, which, added to their variable nature, renders it difficult to determine a really characteristic section. One which was roughly measured by me gave a band of conglomeratic slates, underlaid by 100 feet of non-conglomeratic slates, below which were conglomeratic bands occurring with quartzites through 200 feet, while 50 feet below these came a band of pink limestone, resembling the Blaini limestone.

This exposure is referred to by Col. McMahon, who declared that "it is beyond all reasonable doubt that the rocks here seen are the Blaini rocks."[1] I think it is beyond all reasonable doubt that they are the same as my Mandhális of Jaunsar, which they resemble very strongly in physical character and in their superposition on a massive limestone series.

Whether the Blaini and Mandháli rocks are of the same age or not I shall leave for a separate paper on the boulder-bearing slates of the Himalayas, but it is necessary here to remark that I could find no proof of unconformity between the boulder beds and carbonaceous slates; but the irregular appearance of the former points to an unconformity of both on the Deoban limestone. The same is proved by the presence of fragments of the latter rock in the former, and in this it agrees with the Mandhális of Jaunsar.

Before leaving this subject I must notice that in the exposure east of Chepal there is a small patch of a rock which very strongly resembles a volcanic ash. The rock is exposed on the very crest of the ridge and is almost immediately cut off by a fault; what remains is very much decomposed, but I notice it, as this is the only case I have seen where a rock associated with the boulder beds has presented more than the most superficial resemblance to a volcanic rock.

The volcanic rocks of the infra-Krol series.—On the spur south of the Minas gádh, leading east from the Chor, in the Deora valley of Jubal, on the Narkanda-Sungri ridge and on the Lambatách ridge between the Tons and the Pabar, I found volcanic beds associated with the black carbonaceous slates. These beds differ in age and character from those of the "Lower Chakrata" series; the specimens have not yet been examined in detail, but, speaking broadly, it may be said that they are of a more decidedly basic character than the Lower Chakrata volcanics.

These are the same beds as are described from the Sutlej valley[2] by Col. McMahon, who correlates them with the volcanics of Dalhousie and Cashmir.

The gneissose granite of the Chor.—As the Chor was deeply covered in snow when I was in that neighbourhood, I did little more than take a passing glance at the eastern margin of the granitic intrusion. The intrusive nature of the gneissose granite having been proved already, it is not necessary to consider this point in detail, but I may say that the manner in which the boundary of the granite cuts across the bedding of the adjoining sedimentary rocks, as well as the numerous inclusions of schist and quartzite, make it very evident that the rock of the Chor is a granite by origin.

I was, however, able to make one observation which has an important bearing on the mode of intrusion of the granite. On the spur south of the Minas gádh the

[1] Records, G. S. I., Vol. X, 210. [2] Records, G. S. I., Vol. XIX, 67.

black carbonaceous slates are overlaid by the volcanic beds noticed above, here changed by contact metamorphism into hornblende schists and mica traps. On the spur north of the Minas gádh no trace of these rocks can be seen, but in their place is an exposure of a rock which only differs from the porphyritic rock of the Chor generally, in that the matrix is highly hornblendic, and consequently dark coloured, thus throwing up the porphyritic crystals of orthoclase with great distinctness.

I do not see any possible explanation of these facts unless we suppose that the granite dissolved and absorbed the rocks, whose position it now occupies. On this supposition its locally hornblendic nature, where it replaces hornblendic rocks, is easily explicable, while the very slight disturbance of the surrounding beds, as well as the steady dip towards the Chor, are inconsistent with the supposition that the granitic intrusion was either the cause or consequence of disruption of the sedimentary beds.

The gneiss series of the Upper Pabar valley.—In the upper reaches of the Pabar valley and its affluents there is exposed a series of beds which, whether we have regard to their lithological structure or their mode of origin, must be classed as a gneiss series. For the most part the beds are gneiss, but they vary in one direction to nearly pure felspar, in the other to a very slightly felspathic mica schist; some beds are schistose greisen, and there are a few of metamorphic quartzite whose sedimentary origin is easily recognizable. The foliation is parallel to the bedding planes, and the whole is most palpably metamorphic, using that term as opposed to intrusive, and without reference to whether these rocks ever were or were not ordinary sediments, such as those the slates have been formed from.

Many of the beds of gneiss contain porphyritic eyes of orthoclase, sometimes two or three inches in length. As regards internal structure, they resemble the porphyritic crystals of the gneissose granite, being composed of a single twinned crystal of the Carlsbad type, but they differ in their external form, which is lenticular, and in their invariable arrangement, with their greatest diameter along the plane of foliation. Doubtless it was by fusion of this rock that the intrusive porphyritic granite originated.

The position of this rock is very clear, for the beds lie very flat for the Himalayas. It unconformably underlies a series of red quartzites, which, near the Búran (Borenda) pass, are overlaid by beds containing hornblende schist. I have little doubt that these represent the "Lower Chakratas" and overlying volcanic beds, the lithological similarity between the quartzites being especially striking.

Arkose beds of the Lambatách ridge.—On the Lambatách ridge there is exposed a series of beds presenting many points of interest which, owing to the coming on of the monsoon, I was not able fully to investigate. The beds consist in part of the fine grained felspathic quartzites which extend into Bawar, and were there described by me as the Bawar quartzites. But below these comes a great thickness of more or less schistose beds containing granules of felspar. In the Kotigadh (Kunjado R.) the rock is at first sight difficult to discriminate from the porphyritic granite, which it resembles also in its mode of weathering. But on closer examination it is seen to decompose more readily, and a close examination will generally show that the felspar consists of broken crystals, while not infrequently small pebbles may be detected. Another feature which separates it from the gneissose granite and unites it to the felspathic grits is the abundance of granules of pale blue transparent quartz.

These rocks pass upwards into black carbonaceous slates and limestones, associated with volcanic beds, which in all probability are the same as the *infra*-Krol carbonaceous slates. If this be so, the arkose cannot have been derived from the porphyritic granite, which is found intruded among carbonaceous slates on the Chor and in the Deora valley, but must have been derived directly from the archæan gneiss.

It seems probable that these arkose beds indicate a severe climate, as it is evident that the disintegration of the rock from which they were derived must have been more rapid than the decomposition of its constituent minerals. This view receives some confirmation from sections exposed in the road cuttings in the Deota forests; some of these beds of coarse grit have scattered through them boulders of quartzite, ranging from a foot and more in diameter. With so coarse-grained a matrix this does not prove glacial origin, unless it could also be proved that the beds were not of subaërial origin; for large boulders may often be rolled along the surface of a much finer deposit, where the latter is formed by shallow streams. But, as there is no direct evidence of a subaërial origin of the felspathic grits, it seems natural to take these boulders, combined with the undecomposed felspar, as indicating a severe climate.[1]

It may be noticed that the arkose beds appear to hold much the same relation to the carbonaceous slates as the presumably Mandháli boulder slates do to the carbonaceous slates of the Chor and Chepal. The latter, there is every reason to believe, are of glacial origin.

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal and Kumaun, Section II, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

In the last number of the "Records" I described Dudatoli Mountain from a petrological and structural point of view. The present paper will be devoted to a short account of some ancient Rhyolites and associated rocks which adjoin the Dudatoli area on the east. Their geological importance depends partly on the fact that they are the first representatives of an acidic type of lava that I have met with in British Garhwal, partly on their situation among a set of formations sharply marked off from the neighbouring schistose area, and chiefly on the circumstance that among them exists a transitional form, connecting petrologically these ancient acidic lavas with the gneissose granite of the Dudatoli ridge. This is the first time that any of the gneissose granites of the Himalaya have been shown to be connected with a subaërial lava flow: and the coincidence seems to finally clinch the argument and set at rest the controversy concerning the eruptive character of the gneissose granite. Strictly speaking however, it only demonstrates that a portion of the gneissose granitic material was drawn upon by volcanic vents; and, as this

[1] I have found that gneiss and granite disintegrate into felspathic sand, in which the felspar is undecomposed, at elevations of 14,000 feet and over in Ladák. I have never seen a material which could consolidate into arkose at the lower elevations, up to 10,000 feet, of the outer Himalayas.

material may have come from a source vertically far above where the Dudatoli ridge now is, the deeper-seated magma now represented by the Dudatoli rock may never have had much of a demand made upon it by the volcanic action above, to rush into eruption, and so may never have possessed much motion relatively to the intruded rock. I will describe these erupted lavas, and the formations among which they occur, by reference to a locality where I first hit upon them.

LOBAH VOLCANIC ROCKS.

The map facing page 142 of the last number of the "Records," at its east margin, is contiguous to a great faulted boundary running nearly north by west as far as the Dewalikhal pass, and then veering further west as it skirts the north-east portion of the Dudatoli massif. This fault can be traced for 20 or 30 miles forming a great dividing line between the old schistose series among which the gneissose granite is insinuated, and the younger set of lavas and more nearly related formations with which the gneissose granite is approximately contemporary. A few miles from the fault these younger formations, in the vicinity of Lobah, have a fairly steady dip towards the east-north-east; but near the fault they are forced into a few close folds, with subordinate faulting, nearly parallel with the great fault itself.

The strike of these rocks may be put down as very nearly N.N.W. to S.S.E. They, therefore, cut directly across the strike of the schistose series, which is roughly W.N.W. to E.S.E.

The lowermost of the younger set of formations, east of the fault, is a limestone of dark blue-grey co'our, and massive appearance; only differing from previously described limestones of this type by the presence of nodules of chert in some of its upper layers. This formation peeps out from underneath the volcanic rocks in longer or shorter anticlinal domes, and is well exposed in the stream beds which join the Ramganga from the east. I hazard nothing at present concerning its age. A short thickness of glassy looking quartzite is superposed in some sections.

A great unconformability, with attendant conglomerate, ushers in the volcanic rocks. The conglomerate, which it will be convenient to call the Lobah conglomerate, varies considerably within a few miles of outcrop; and vertically also it changes very rapidly. Its strongest feature is a large, well-rounded, torrent-boulder bed; the pebbles being from a few inches to a foot in diameter. They are chiefly quartzite, of that hard and glassy kind found immediately beneath the conglomerate. I found no pebbles whose constitution could be called a quartz-schist. A few limestone pebbles were occasionally present. The whole is coherent, as a massive and exceedingly hard rock, with a little cementing material of coarse quartzose and slightly calcareous substance. In certain localities the pebbles are scarcer, and the basal conglomerate is then a conglomeratic, faintly schistose slate, or ashy slate. It is sometimes absent altogether, and the limestone is directly overlaid by the faintly schistose slates. South of Lobah, however, the section is complicated by the introduction of a more decided volcanic element. Along with the larger pebbles there appear angular fragments, and the matrix of the rock changes and assumes a hard dark-green compact aspect suggestive of a felsitic nature. This gradually frees itself from the rounded pebbles, the angular fragments remaining, and more and more

resembling brecciated portions of a flow similar to that of the matrix, but of a lighter tint. Further south, near Suini, purer rhyolitic rocks set in; the whole series tending to become thicker in this direction. There are now displayed several varieties of a compact type, and others slightly vesicular. In the small stream $\frac{1}{8}$ mile N.E. of Marwara village, near Lobah, I found the rock mentioned above as intermediate between the ancient rhyolites and the gneissose granite of Dudatoli. The whole of these volcanic rocks, together with some subordinate beds of dark grit, ashy grit, brown and yellow non-schistose quartzite, and some steatitic slates, cover the massive limestone as a skin, down the face of the hills on the east side of the Ramganga river. Owing to this position, modified by faulting, it is sometimes difficult to trace their exact stratigraphical relations; but they seem to merge upwards, with sometimes an intervening thin band of cream-coloured limestone into slightly schistose slates and schistose ashes. The latter, in many places high up in the series, become very basic in character; whilst the whole of the series is entirely different from the schistose series west of the great fault. I may here mention that N.W. of the Dudatoli massif another set of acidic lavas are found along the ridge 3 miles west of Dobri trigonometrical station. There seems no doubt that they are of the same age as the Lobah flows.

At this point it will be convenient to close the description of these rocks, so far as their field relations go, and to describe them more minutely by means of a set of specimens. These and their accompanying microscope slides will be referred to by their registered number. Thus labelled, they are now in the Geological Survey Museum, Calcutta.

Specimen No. $\frac{7}{755}$.—This rock was found near Sainji, about $\frac{3}{4}$ mile on the pathway to Suini M., Sp. gr. 2·70. Contains 79 per cent. of silica. Before the blowpipe it fuses with difficulty on the edges of thin splinters. In the hand it is a compact rock of a pale grey-green colour, sometimes flesh-white, and altered much by weathering. It breaks with a flinty fracture. It appears dotted over in many place by white spots about the size of pin-heads. These, which I first thought were spherulites, are small gas-pores, filled with an alteration product in the form of amygdules.

Microscopical.—Under the 1 inch objective the field of the microscope is filled by an almost structureless ground-mass, containing no porphyritic crystals, or included fragments of any kind. There is only a faint indication, here and there, of a gathering of the material of the ground-mass into hazy clusters. The gas-pores appear merely as round holes in the slice. Under the $\frac{1}{4}$ and $\frac{1}{8}$ inch objectives the ground-mass is seen to possess a clear base, which, with ordinary transmitted light, cannot be split up into grains, but appears uniformly amorphous. Through it are scattered in the wildest profusion and without any order a countless number of microlites, very small, and of irregular shape. They are sometimes more or less rounded, sometimes elongated needles; but more often of an irregular form longer one way than another. There is no spicular arrangement, as in the Arran pitchstones, no dendriform structure, and no trace of spherulites. The only thing noticeable is that in some places the microlitic groupings are denser than in others. The microlites are pale yellowish green in colour. Minute specks of opacite are only sparingly represented, except in connection with the gas-pores, which are more or less

lined by them. The microlites cannot be regarded as having any claim to a crystalline structure; for when the nicols are crossed, they have no influence on polarized light. Their outline can then only dimly be seen through the base, which becomes divided up into irregular polygonal patches of light, and dark blue-grey colour, whose boundaries are very uncertain. These outlines are quite independent of the position of the microlites, a fact indicating that it is the base alone in which the microlites lie, which has been altered molecularly, and which behaves under crossed nicols something like a crystalline aggregate. It is necessary to note, then, that the visible structure under ordinary light is replaced under crossed nicols by a previously invisible structure; and the microlites, though not absolutely vanishing from view, can only be seen with difficulty. They have only a negative influence on the light. They seem to run in among the petrosiliceous material which now, in contradistinction to the microlites, shews its inherent differences of molecular constitution by its positive effects on the light.

The rock would seem from this to be a petrosiliceous rock, with a confused devitrified base, crowded with minute microlites. The mottled or mosaic-like appearance of the base under crossed nicols seems to indicate that quartzose and felspathic minerals are separating out, though they have not done so so entirely as to be visible under simple transmitted light. The question arises, what was the destiny of the microlites; would they have been absorbed, or would they, if progress had not been arrested by solidification (as seems indicated by their yellowish colour), have become some other mineral, such as mica or hornblende?

Specimen No. $\frac{7}{156}$.—This specimen is taken from the crags above Rheetheea Tea Factory, near Lobah. Sp. gr. = 2·65. I at first overlooked this rock in the field, taking it for a quartzite, as it weathers on the surface exactly like one. A freshly broken specimen shows it to be entirely different, with a dark green ground-mass, vaguely showing flow-structure and full of angular fragments of compact, lighter tinted rocks, flesh-coloured, and sometimes pale greenish grey. It is a very beautiful rock, and undoubtedly forms a portion of the same flow as No. $\frac{7}{155}$. It appears to pass into the Lobah conglomerate by the fragments becoming more and more rounded, and the petrosiliceous matrix becoming less pronounced, or replaced by fine clastic material. (See above.)

Microscopical.—Under the 1 inch objective the rock is seen to be as much clastic as volcanic. The ground mass is of an olive green colour, showing very distinct flow structure. The fragments of other petrosiliceous rocks included are angular and of all shapes. Their intimate structure is very like that of the previously described specimen; and they probably represent caught up dust and fragments of older flows which have become brecciated. No doubt both the included fragments and the enclosing rock were practically of the same age. Quartz is also present in small grains, all of which are angular and the remains of more or less perfect crystals. There is a certain amount of black and dark brown opacite. Small cracks in the rock are lined by secondary quartz, chalcedony or "quartz grenu." Under the $\frac{1}{4}$ inch objective the ground-mass can be discerned as having a clear base like the last described rock; but it is more thickly crowded with pale green microlites, which are clustered together in irregular patches, as well as being generally disseminated through the base. These green microlites have apparently but little effect

optically, except that their density prevents so much light passing through under crossed nicols as there would otherwise be. The mosaic appearance of the base is consequently to a large extent shrouded. I could not see any, or very little polarization colour due to the microlites, as the stage was revolved, such as can be made out in the rock next to be mentioned. Doubtless the microlites in this case were just too small. The flow-structure, which is very prominent, is manifested by differences in the amount of colour and in the fineness of the bands of microlites.

Altogether, the rock exactly resembles a brecciated, devitrified rhyolite, in which a considerable quantity of fragments of other flows have become mixed or caught up.

Specimen No. $\frac{7}{757}$.—Loose block in the stream east of Saliana near Lobah and found *in situ* $\frac{1}{2}$ mile N.E. of Marwara near the road to the Dewalikhal pass. Sp. gr. = 2·73. This rock links the gneissose granite of Dudatoli with the ancient rhyolites and brecciated rhyolites just described in detail. It seems to have a matrix very similar to that of the rhyolites themselves, and dispersed through it are large eyes and more or less rounded crystals of felspar, which give it a porphyritic augen structure. It has also plenty of free quartz in large irregular grains. I take the following extract from my field note-book:—"Matrix, a dull pale greenish grey, perfectly compact so far as the eye can see, save for a flow structure and faint banded appearance, dividing it into sinuous lines of paler and darker colour. The contents distributed in the matrix are a smaller set of granules of somewhat dark quartz, and small rounded eyes of felspar. Its porphyritic nature is given to it however by the presence of large eyes of felspar, rounded and oval, between which, as well as between the smaller particles, the matrix appears to have flowed. In some cases the eyes of felspar, especially the larger ones, have become cracked and partially displaced, and the matrix seems to have flowed in between the adjoining portions and so encompassed them."

Microscopical.—This rock, so far as its ground-mass is concerned, is very slightly coarser than No. $\frac{7}{756}$, the green mineral being rather more strongly represented by somewhat larger microlites. Like it, however, it is of an olive green colour, and by small differences in tint and in the density of the microlites, flowstructure is manifest among the petrosiliceous material which has found its way between the porphyritic crystals and included fragments scattered through it. Under the higher powers of the microscope the evidence of its having flowed is added to by a vaguely linear arrangement of the microlites, indicating that they had become turned more nearly parallel to the direction of flow, as they were swept on in the molten current. Of the porphyritic elements in the rock the large orthoclase crystals are the most conspicuous. They are of an opaque porcellaneous appearance under a low power, and have a very ancient look, disfigured by a corroded outline, and by the ramifying of innumerable veins of secondary quartz through them, and also by portions of the ground-mass, full of microlites, being similarly thrust in between widely open cleavage cracks at right angles to one another. The secondary quartz was introduced last of all, for it cuts through the ground-mass in the matrix and through the tongues of the same which penetrate the orthoclase. The free quartz is usually arranged in hexagonal groupings of three or more crystals, with some of their outlines fairly intact and with others corroded away and jagged, indicating that, though the quartz

had crystallized out originally, it had suffered considerably during its transit in the molten flow. In one place a portion of the compound crystal was very nearly separated from the rest by inclusions of the ground-mass along parallel cracks; which gave the nearly separated portion the aspect of being connected by threads with the remainder, and ready to part at any instant. Secondary quartz along lines of infiltration invades the crystalline quartz also. Innumerable minute cavities throng the quartz, but they are unresolved under the $\frac{1}{8}$ inch objective.

Besides porphyritic orthoclase and quartz, there are also portions of other petro-siliceous flows in rounded fragments, a few sharply marked off from the ground-mass, but mostly appearing as half fused up and amalgamated with the ground-mass. Distinct irregular clumps of opacite are present in fairly large quantities.

Under crossed nicols, as in the previous cases, no undifferentiated glassy base can be satisfactorily made out. The grey-blue mosaic indicates at once devitrification structure, which is not quite so much obscured as in the previous rock slice. The general effect is not quite so dark. The embryonic quartz and felspar appear to have gone a little further towards separating out into distinct granules. Without the crossed nicols, however, this separation is quite invisible. Under the $\frac{1}{4}$ and $\frac{1}{8}$ inch objectives the microlites of the green mineral are seen to be rather larger than in the last rock, and to have a decided effect on polarized light, so that when the nicols are crossed, the somewhat parallel microlites light up the field of the microscope with multiform coloured brush-like aggregates.

From all points of view this rock must be considered akin to No. $\frac{7}{766}$, save that it contains crystals of the "first consolidation," *viz.*, porphyritic quartz and felspar. It may therefore be called a devitrified porphyritic rhyolite. Had the rock solidified under a pressure of super-incumbent rock and cooled slowly, it seems probable that it would have resulted as a microgranulitic rock or elvan, with the porphyritic addition of quartz and orthoclase. It would be difficult, therefore, to deny it an intermediate position between the gneissose granite of Dudatoli and the purer rhyolitic lavas.

Specimen No. $\frac{7}{768}$.—This is from the same locality as No. $\frac{7}{766}$. Sp. gr.$=$3·03. It is undoubtedly a vesicular variety of the purer rhyolite. In the hand it is pale whitey green in colour, splitting with some difficulty along the direction of original flow. Under the microscope its only peculiarity, as distinguished from No. $\frac{7}{766}$, is the large number of gas-pores, which are filled with reddish iron oxide. These account for its high specific gravity; for another fragment taken from the same piece of rock, but less full of amygdules, has a specific gravity of only 2·66.

Specimen No. $\frac{7}{769}$.—Sp. gr.$=$2·63. This rock is not from the locality of Lobah, but from the stream-head running west to Peera from the Dobri ridge. It is mentioned here because it links the thoroughly brecciated and clastic forms of the rhyolite with the amorphous compact varieties. It is pale grey or whitey green in colour, showing a distinctly banded structure, which has in places become interrupted by one of the bands becoming distorted and brecciated, and by the interbanding of minute rounded quartz grains, suggestive of a fragmental origin. This structure clearly evinces that partial cooling had been followed by further flowing of the semi-solidified mass.

These few examples are sufficiently typical of the acid lavas and their allied forms, as developed in the neighbourhood of Lobah. Others from localities N.W.

of the Dudatoli massif will be described in due course, and also some allied compact red porphyrites, or ancient rocks, of a less acidic character, found near Charmarguri trigonometrical station. There also remain to be considered the basic lavas which seem to replace or overlie the acidic lavas at some parts of the margin of the Dudatoli area. Though far more abundant than the ancient rhyolites, I have deferred their examination until later, because their connection with the gneissose granite seems to be inadmissible. It is indeed difficult to account for the plutonic representatives of these lavas; nevertheless, until the district is completely mapped, it is unsafe to say that they have no such representatives.

I will conclude these petrological notes by a reference to the differences in metamorphism between the old schistose series west of the great fault near Lobah, and the very slightly schistose rocks which lie to the east of it. The garnets, and well developed plates of mica, which characterize the old schistose series end abruptly at the fault. Now, as was shewn in my last paper, the production of garnets in the schist and the appearance of the Dudatoli gneissose granite must have been contemporaneous, and probably inter-dependent. It therefore follows that the argument for the great age of the gneissose granite previously founded on other and more general grounds, is now buttressed by this additional fact concerning the distribution of the contemporary metamorphism.

The Iron Industry *of the* Western Portion *of the* District of Raipur, *by* PRAMATHA NATH BOSE, B.Sc. (Lond.), F.G.S, *Deputy Superintendent, Geological Survey of India.*

Literature.—The notice taken in the article on "Raipur" in the *Central Provinces* Gazetteer (published 1870) of the iron-ores of the district is very poor. Only two localities are mentioned, and not a word is said about the mode of occurrence, the extent, or the working of the ore. It is no wonder, therefore, that Mr. Ball, the accomplished writer of the "Economic Geology of India," should have summarily disposed of the iron-ores of the Raipur district by saying, "Little or nothing is recorded as to the iron-ores of this district."

In Appendix III, G. (Mines and Quarries) of the last number of the Central Provinces Administration Report (1885-86), half-a-dozen iron-ore localities are mentioned as occurring in the district of Raipur, *viz.*, "Kondkasar, Bhindo, Lahora, Dalli, Sambarsingha, and Magarkund." The history of several of these names is not without interest. In the Administration Report for 1868-69 the names given are "Condkusar, Bhindo and Lohara, Dallee, and Muggurkund." Two years later we find "Lohara" separated from "Bhindo" and joined on to Dallee as "Lohara-Dullee;" it was subsequently again disjoined from Dallee, and transformed into "Lahora." But I know of no place of that name in the Raipur district where iron-ores occur.[1] "Lohara-Dalli" would be more intelligible, for the hill of Dalli,

[1] There is a Lohara hill in the Chanda district where iron-ores of good quality are known to occur.

which is full of iron-ores, one variety being the richest as yet found in India, being situated in the Daundi-Lohárá zamindári. "Bhindo" and "Sambarsingha," I have not yet been able to identify.

2. *Extent of the ores.*—The number of places where iron-ores and smelting furnaces exist is much larger than that given in the statistical tables cited above. Of the localities noted by these, Magarkund is the only one where the ores are still worked, the furnaces at Kondkasar, Dalli, &c., having been given up for some time past. On the other hand, as will be seen from the following list, there are numerous places not mentioned in the statistical tables where I saw furnaces at work (season 1882-83.) The number of these is very variable and must be taken as approximate. The *Agarias* who work them are a very unsettled people, leaving a place as soon as the neighbouring jungle fails to satisfy their requirements, or the zamindár enhances the duty levied on their furnaces.

I. GANDÁI ZAMINDÁRI.

Magarkund.—Here the ore worked is red hæmatite occurring as nodules in alluvium a mile and a half north-east of the village at the foot of a hill of red ferruginous Chilpi (? transition) sandstone. The ore is evidently derived from the latter. I saw eight furnaces at work in the village.

II. THÁKURTOLA ZAMINDÁRI.

(*a*) *Chutrala (deserted).*—The ore is like that of Magarkund in extent and mode of occurrence. It is no longer worked.[1]

(*b*) *Kumi.*—Here the ore is of considerable extent and occurs in lateritic beds overlying black basaltic rocks which appear to be intrusive in the Chilpis.

(*c*) *Basantapur* (not marked on map).—A village near Kumi, several smelting furnaces are at work here. Ore as at Kumi.

III. NÁNDGÁON FEUDATORY STATE.

Lateritic ore abundant over an area of eight square miles, at *Bháwá, Jurlákhár* and *Chuhuri* (depopulated), now worked only at *Jurlakhar*,[2] where I saw four active furnaces.

IV. KHAIRÁGAR FEUDATORY STATE.

In the western portion of this state north of Dongargar is a jungle-clad hilly country, which is full of iron-ores. These are very largely worked, there being furnaces at *Borlá, Katulkassa, Banjár* (not marked on map), &c., probably aggregating twenty in number. The ores mostly occur in soil covering basaltic rocks which appear to be intrusions in the Chilpis; but rich hæmatite, among beds of red sandstone, is also met with.

V. WORÁRBAND ZAMINDÁRI.

West of *Worár* a mile south of the great eastern road from Nagpur to Raipur, I found iron-ore in lateritic deposits covering beds of hard, red, nearly flat sandstone (Chandarpur). The country is poorly wooded; and, as far as I could ascertain, it has never been utilised.

[1] Last season furnaces were working at Murwabhat, 3 miles south-east of Chutrala.

[2] From information last season (1886-87) I learn that the village is now deserted.

VI. DÁUNDI-LOHÁRÁ ZAMINDÁRI.

The richest and most extensive ores of the district are to be found in this zamindári. Furnaces exist at *Killákorá, Ungárá, Hirkápár*, &c. The hill of Dalli, for about 7 miles of its length, is full of good hæmatite, which is developed in hard, red, rather thin bedded ferruginous Chilpi sandstone. The villages of Dalli and Kondekassa once possessed a very large number of furnaces, but they have been given up, owing, I heard, to the Zamindár of Lohara having raised the duty levied on iron furnaces.

3. *Analyses.*—Four specimens of the ores brought by me were analysed by Mr. E. J. Jones, of the Geological Survey, with the following result:—

	Percentage of iron.
1. Dalli	72·92
2. Do.	67·41
3. Chutrála	63·82
4. Worarband	53·24

4. The first variety of the Dalli ore appears to be the best that has as yet been found in this country, as will be seen from the following comparison:—

	Dalli. (Raipur.)	Lohara hill.[1] (Chanda.)	Agaria.[2] (Jabalpur.)	Sanlow.[3] (Rájputuná.)	Dechaun.[4] (Kumáon.)
Percentage of iron	72·92	69·208	68·28	66·00	55·13

5. *Fuel and Water Supply.*—All the places mentioned above, except Magarkund and Worarband, are situated in fairly wooded forests; and those near Dalli, especially to the west and south-west of it, are exceptionally good, so much so that a charcoal furnace on a large scale could possibly be maintained here to advantage. The fuel used for reduction of ore in the furnace is obtained from *Dhaora, Salai* and similar trees of comparatively little economic importance, teak and other timber-yielding trees being not allowed to be cut down for the purpose. For refining, bamboo charcoal is employed.

Of all the places tabulated above, Dalli is most advantageously situated as regards supply of water, several springs in the neighbourhood yielding it in a very pure form. Mr. E. J. Jones of the Geological Survey, who kindly analysed a sample of the spring water, detected the merest traces only of lime and chloride in it.

6. *Flux.*—Flux is never used in the furnaces which I saw at work. The Raipur (Lower Vindhyan?) limestone is usually not far off from the iron-ore localities. As regards Dalli, the nearest outcrop of it is at a distance of 20 miles. One specimen of the stone, analysed by Mr. Hiralal, of the Geological Survey, gave the following result:—

Carbonate of lime	83·50
„ „ magnesia	2·00
Oxide of iron and alumina	0·90
Insolubles	13·60
	100·00

[1] "Manual of the Geology of India," Vol. III, p. 388.
[2] Records, G. S. I., XVI, p. 97.
[3] Manual, III, p. 395.
[4] Ditto, p. 409.

7. *Mode of working*, &c.—The furnaces are of a primitive character, not unlike those described at p. 380 of the "Manual of the Geology of India," pt. III. The ore selected is almost invariably the softest, though not always the best, available. The metal turned out by the furnace is refined in an open hearth, and is made into bars called *chuls*, which are sold to blacksmiths at an average rate of five annas per *chul*. The outturn per day from each furnace, supposing eight persons to be employed for preparing and bringing fuel and ore, and for working at the bellows, would be four *chuls*, selling at one rupee four annas.[1] Fixing the wages of work-people at two annas per head, this leaves a margin of four annas for the proprietor. The duty on the furnace has to be paid from this sum, and it may be as low as one rupee, and as high as seven rupees per annum. This, however, is inclusive of all dues on account of trees cut down for charcoal. As the only expensive portion of the apparatus employed is the bellows, which costs from three to four rupees, and as the proprietor's supply of labourers is usually drawn from his own family, he being one of them, iron-smelting is considered a fairly profitable industry where fuel is abundant, and the duty on the furnace not too high.

The furnaces are worked by a class of Gonds who style themselves *Agariás* or *Pardháns*. They almost invariably speak the Gondi language, which their brethren of the plains have quite forgotten, and would not scruple to eat cow, buffalo, &c., which the latter, who aspire to the title of Hindus, would never touch. Iron-smelting must be a very old industry with the Gonds. Their traditions ascribe their first settlement in *Káchikopá Lahugarh*, or the "Iron valley in the Red Hills;" and the only metal for which they appear to have a name in their language is iron.

Notes on Upper Burma, *by* E. J. JONES, A.R.S.M., *Geological Survey of India* (with 2 maps).

1. The Chindwin Valley.
2. The Panlaung Coal-field.
3. Two Coal Localities in the Shan Hills.
4. Lignite at Thigyit near Nyaungwe.
5. Metalliferous Mines in the Shan Hills.

1.—THE CHINDWIN VALLEY.

Recent and alluvial deposits.

The strata exhibited in the Chindwin river at Monywa, the lowest point which I visited, consist of recent sand, resting on a ferruginous conglomerate containing fragments of the well known fossil wood[2] so widely distributed in Burma. I found this fossil wood at almost the highest point to which I travelled on the Chindwin (the neighbourhood of

[1] From the manner in which the operations are performed, it is impossible to form anything like a correct estimate of either the outturn or of the working expenses.

[2] Derived from the "fossil wood group," of Mr. Theobald. See Memoirs, G. S. I., X, p. 247.

the mouth of the Kalé creek), and as far east as a short distance from the base of the Shan Hills; while according to Mr. Theobald it is of very wide-spread occurrence in Lower Burma.

At Alon, 5 miles up the river above Monywa, the same conglomerate is seen dipping slightly towards the east.

Tertiary.

Above Alon the banks are low and sandy for some distance, but a few miles above the station, a ridge of sandstone, which, from the launch in which I was travelling, appeared horizontal, but which probably dips, as do the strata everywhere in this part of the country, to the east, is seen running across the river from east to west and forming a low cliff on each bank.

Above this point the right bank becomes less sandy and higher, while the left bank remains low and chiefly composed of sand. Another ridge of sandstone runs across just by Yathit.

Above this point similar sandstone frequently appears in both banks, though at the time I visited the locality the channel was frequently separated from the actual river bank by wide stretches of sand-bank, between which the little water that was left in the river flowed.

Some miles below Kani the banks become quite low and sandy again, but at Kani there is a precipitous cliff, just above the village, formed by a small range of hills running nearly north-south, which here crosses the river.

At the bottom of this cliff, which is about 200 feet high, there are 20 feet of coarse ferruginous conglomeratic sandstone, above which the sandstone becomes much finer and lighter coloured, being of a light buff, though bands of the darker coloured ferruginous sandstone are to be seen at intervals all the way up.

Above Kani the banks gradually become low again till, at about 17 miles below Maukadau, the river passes through a much higher range of sandstone hills. Above this the river becomes wide and much spread out, and blocked with sand-banks, though low hills are always to be seen at no great distance from the river.

Above Mingin soft sandstones are seen on the right bank dipping to the east under the river; the left bank is fairly flat with an occasional small outcrop of the sandstone.

Cretaceous?

At the junction of the Kalé creek (or Myit-tha) a fine-grained greenish yellow sandstone, harder at and near the weathered surface than inside and containing courses of a harder sandstone, is exposed dipping to E.15°S. at 30°. The harder courses are due to infiltrated silica and ferruginous matter. This sandstone also contains in parts ferruginous nodules and bands of a somewhat coarser texture.

Position of the field.

The Kalé Coal-field.—This is only a small portion of what promises to be a much larger field. It owes its name to the fact of some coal having been found and worked to some extent in the so-called Kalé creek (the Myit-tha), which flows into the Chindwin at the village known as Kalewa (Lat. 23° 4′ N., Long. 94° 25′ E.), situated on the right bank of the Chindwin between Mingin and Kindat.

Other coal seams on the Chindwin.

I was informed by those who had the opportunity of observing the neighbouring country that this is by no means the only tributary of the Chindwin in which coal occurs, but that it is to be found in almost, if not quite, all the streams flowing in on the right

bank below the Kalé creek, and to the north of this point as far as Tamu. Coal was also reported by Captain Stevens through the Political Agent, Manipur, in 1886 to occur in large quantities in the Kubo valley, though Captain Stevens did not think it would ever be able to compete with the Kalé coal.

Coal in Kubo valley.

The only coal locality I visited was that on the Kalé creek. The coal is here found out-cropping in the right bank of the stream about $2\frac{1}{2}$ to 3 miles above its junction with the main river, and just below the villages of Thitcho on the left bank, and Chau-oung on the right bank. About a $\frac{1}{4}$ mile below Chau-oung a small stream runs into the creek from the south, immediately below which the main seam of coal is exposed.

Position of the coal outcrops.

The whole section as seen is as follows in descending order, the dip being to the east at 45°:—

Strata.	Thickness. Ft.	In.	REMARKS.
1.—Sandstone	5	0	Only 5 feet are exposed, the upper portion being concealed by alluvial clay.
2.—Carbonaceous clay, with bright jetty bands of coaly matter.	2	0	
3.—Fine bedded shales	20	0	
4.—Hard, calcareous, shaly sandstone containing fragments of fossil plants.	2	0	This is however only a local bed, as it thins out and disappears within 20 feet.
5.—Shale containing concretionary masses resembling No. 4.	50	0	
6.—Coaly matter	2	0	This is the maximum thickness; it varies from 2 ft. to 6 in. and back to 2 ft. within a few feet.
7.—Carbonaceous sandy shales . .	10	0	
8.—Sandy shales	20	0	
9.—Clayey shales	30	0	Contains courses of exfoliating ferruginous lumps in the undecomposed centre of which are fragmentary plant remains by the talus from a small stream.
Here the section is concealed for 150 feet.			
10.—Hard band of a heavy stone similar to No. 4.	1	0	
11.—Shales	30	0	
The section is here again concealed			for a few feet.
12.—Very much broken and partly decomposed blue shale.	5	0	Nos. 12-16 were exposed in the quarry.
13.—*Good Coal*	10	0	
14.—Inferior coaly shale . . .	1	9	Useless.
15.—Brown clayey shale, with strings of coaly matter.	1	7	
16.—Grey shale	7	0	7 feet is all that is seen of this grey shale, 5 feet are seen in the coal quarry and 2 feet below the quarry; the concealed interval is at most 4 feet.
Carried over .	197	4	

Strata.	Thickness. Ft.	In.	REMARKS.
Brought forward	197	4	
17.—Coaly matter	0	9	
18.—Clayey shale	1	0	
19.—Coaly matter (Ft. 0, In. 5); Clay shale (Ft. 0, In. 7); *Coal* (Ft. 1, In. 0)	2	0	The clay shale is a mere local bed which thins out in a few feet.
20.—Shale, with coaly strings	12	0	
21.—Carbonaceous papyraceous shale	3	0	
22.—Yellowish shales	11	0	
23.—Sandstone	4	0	
24.—Shale	1	0	
25.—Sandstone	1	0	
26.—Shale	5	0	
27.—Carbonaceous shale	1	0	
28.—Yellowish shale	4	10	
29.—Coaly matter	4	7	
30.—Loose shale	2	6	
31.—Good bituminous bright coal	0	6	
32.—Carbonaceous shale	0	10	
33.—Yellowish shale	21	0	
34.—Sandstone	1	0	
35.—Sandy shale, with bands of sandstone.	10	0	
36.—Soft sandstone, with irregular courses of harder sandstone.	30	0	
TOTAL	314	4	

This sandstone (No. 36) forms an escarpment on the east bank of the small stream mentioned above as flowing into the creek just above the coal.

To the west of this stream nothing is seen except the alluvial soil of the bank, till some courses of a hard sandstone are seen just below Chau-oung (about quarter of a mile up the river).

Below the sandstone is a 2-in. seam of bright bituminous *coal* resting on shale, beyond which alluvial soil again covers all.

To the south of this, on the opposite (left) bank of the river, and just above the village of Thitcho, a 2-ft. seam of bright *coal* is exposed, with broken shale above it and grey shale below. The dip here is also to east at 45°.

Above this in the series of rocks (*i.e.*, down the river) are about 39 feet of fissile sandstone and shale, then 6 inches of coal and 1 foot 6 inches of grey shale, beyond which the section is concealed on this side of the river. It is probable that one of these seams corresponds to the 2-in. seam seen on the other side.

Further small seams of coal in tributary streams.

Going up the small stream running into the river just above the 10-ft. seam of coal, nothing is seen for the first mile but fine-grained sandstone (sometimes fissile and much broken) and blue, grey, and yellow shales of the same character as those exposed in the main section. About one mile up on the right bank, there is a band of papyraceous coaly shale varying from 4 to 6 inches in thickness, and covered by grey shale, streaked with black and containing some threads of bright bituminous coal. This must be some hundreds of feet below the seams exposed in the creek, as from this point the stream runs chiefly east and somewhat north, to its junction with the creek, the dip remaining 45° E. all the way.

About half a mile further up, on the left bank, is a great mass of grey and somewhat carbonaceous shales containing a 10-in. seam of *coal*, covered with grey shale and having carbonaceous shale below. The dip here is to E. 10°N. at 35°. About 20 feet further up the stream (*i.e.*, below in the series of beds) is another 2-in. seam of *coal*, and 100 feet further on a seam 1 foot 4 inches thick of *coal* dipping to east at 45°. These coals are all of the same character, being bright bituminous coals with cuboidal fracture, but containing layers of dull coal. About 50 feet further on, below the series of shales and coal, is some very hard slightly calcareous sandstone, containing impressions of fossil leaves, and in which I also found the internal cast of a gasteropod shell.

There is another small stream flowing into the creek on the left bank above Thitcho village, in which a small seam of *coal* (1 foot 2 inches) is seen, with clayey shale both above and below it. The dip here is only 35° to E. About a quarter mile further up is another 1-ft. seam of *coal*. These are both of the same bright bituminous and jointed character.

Up the main creek nothing is seen, as far as I went, of any coal; but there must be some further up, as I found small fragments of coal on the sandbanks in the bed of the river.

Down the river also I saw no signs of coal, the greater part of the rocks, where exposed, being hard sandstone.

Number of the seams.

We have thus within an area of about one square mile ten distinct seams of coal, all, except one, of which are however useless. I was also informed subsequently to my visit of another exposure at some distance from the river on the left bank. There are probably numerous other

small seams in the neighbourhood, though not in such a favourable position for working as the 10-ft. seam, even if they are of sufficient thickness.

Quality and age of the coal.

The coal appears to be of a fair quality, the great drawback being its friable nature. It contains the numerous small veins and pockets of fossil resin noticed in some of the cretaceous coals of Assam, and the Lenya river coal of Tenasserim, which is a good sign as cretaceous coal is more likely to extend to a distance than the uncertain seams of tertiary age. No pyrites can be detected by optical examination.

Value of the seam.

The position is very favourable for working, being in direct communication with the Chindwin. The best and simplest means of carriage would be by water: the coal would have to be loaded into flats at the pit's mouth, and the navigation down stream would probably not present any great difficulties. Another thing on which the value of the seam depends to a very great extent, is its lateral extension and the depth to which it reaches. In order to test this it will be necessary to put down experimental borings, and I have recommended that this should be done as soon as possible.

Position of the mine.

In the borings, it must be remembered that, owing to the high dip of the seam, the coal will appear to be thicker than it really is. Should they give equally favourable results on both sides of the river, I should recommend the mining, at any rate at starting, to be carried on on the left bank, as the ground is there much flatter, with a small plain between the river and the hills, whereas on the right bank the hills come right down to the river. These preliminary trials should be put down by Government in order to see whether the coal extends to any distance.

Stoppage of workings.

The workings which were being carried on at the time of my visit have since been stopped by order, as they were not only ruining the future prospects of the place as a mine, but also, owing to their dangerous nature and the consequent fear of the villagers in digging the coal, there might be great difficulty in procuring labour hereafter.

These workings consisted of a quarry, which was being driven in along the strike in a southerly direction from the river. There are about 20 feet of a coarse gravel (containing boulders 3 feet to 4 feet in diameter) above the coal. The workmen removed the upper 7 or 8 feet of the coal, leaving the upper gravel unsupported, which consequently fell down after the coal had been removed for some distance; indeed on one occasion one of the workmen is said to have been crushed to death.

If there was any one with even a slight practical knowledge of the class of work, the danger could be easily avoided by temporary supports and breaking down the heavy stones before they became loose; but even then the place would be ruined for a mine, as the quarry would subsequently become a means of entry for water and necessitate expensive pumping machinery. On this account I recommended that work should be stopped before any more damage was done.

If coal is, however, required for present use it might be obtained by driving an inclined tunnel on the coal from the top of the bank of the stream to the west, which would reach the coal in 20 to 30 yards, and need not incline downward more than 10°. It should be started where the clay forming the bank begins to cover up the sandstone at the corner where the stream, after running east, turns abruptly north

before running into the Kalé creek; and it should be driven due east: or the tunnel might be started at any point between this and a line drawn due south from the closed workings; in which case it would be shorter, but the inclination would have to be greater.

Specimens of the coal which I sent for assay in Calcutta were unfortunately burnt on the way, so that I am unable at present to give any opinion as to the value of the fuel, as compared with other known coals; but it burns well, and the engineers and serangs on the steamers using it praise it very highly.

Means of transit.

As regards the means of transit, I should decidedly recommend water carriage, as it is ready to hand. I have not been able to see the creek during the rains, but it would probably be navigable for vessels of light draft during all seasons of the year, and the coal could be floated down to the Chindwin in light draft barges.

Supply of labour.

From enquiries I made on the spot, and from the information supplied by Captain Raikes (the Deputy Commissioner), it appears that the supply of labour would be quite equal to the demand when once the people had got accustomed to the class of work, but at first, at any rate, a certain proportion of skilled workmen would have to be imported from India, as the people are quite unused to the style of work. After they had learned the proper way of using ordinary mining tools, &c., this imported labour could be to a great extent dispensed with. At present the only tool they use is a kind of rough spud, such as they use for agricultural purposes.

An efficient European staff would also have to be provided, on whom the success of the enterprise would in a great measure depend.

Disposition by the inhabitants.

The attitude of the surrounding people at the time of my visit was quite friendly and obliging. But, owing to their primitive state, their behaviour would probably depend to a great extent on the disposition of, and the orders or hints received from, the Sawbwa.

Age of coal rocks.

The rocks in which the coal occurs appear, from the presence of fossil resin, and thus by analogy with the cretaceous coal of Assam, which also contains a similar resinous substance, which is characteristic of the cretaceous coals of that region, to be of cretaceous age.[1] The sandstones exposed lower down the creek and in the Chindwin are of lower tertiary, or more probably partly tertiary and partly upper cretaceous age; but I was unable to see enough of the country to determine their age with any degree of certainty.

Opposite to Monywa, at a distance of about 3 miles to the west of the river, there is a hill formed of petrosiliceous volcanic rocks. In this hill,[2] which is known as the Letpadaung Taung, there are the remains of a copper mine, which was formerly worked by Oo Chaung, the younger brother of the Kinwoon Mingyi. Whether he ever obtained any large quantity of copper I was unable to find out, but I should think it very unlikely that the output was at all considerable, as the only traces of copper now extant consist of a few stains of green carbonate. The presence of the volcanic rocks is, however, interesting as forming a further link in the volcanic chain run-

[1] Records, G. S. I., XVI, p. 165.

[2] My attention was called to this locality by Mr. D. Ross, Assistant Commissioner, Alon, who visited the spot with me.

ning north through Narkondam and the extinct volcano of Paopadaung, visited many years ago by Mr. W. T. Blanford[1] who pointed out that Paopa was the continuation to the north of the great eastern line of volcanic outbursts running through the Eastern Archipelago.

2.—THE PANLAUNG COAL FIELD.[2]

The Panlaung river takes its rise near Singulèbyin, and flows northwards by a tortuous course till it eventually joins the Myitngè river, just before its junction with the Irrawaddy near Ava.

Position of the coal field.

The Panlaung coal field is situated on the right bank of the river, near its junction with the Myittha (which flows past Pyinyaung, the first post out of Hlaingdet, on the Shan Hill road). On the map of Upper Burma (1 inch = 16 miles), second edition, published by the Surveyor-General of India, the coal region is not marked as such, but it is situated in the neighbourhood of the spot marked Taungnga village (Lat. 21° 3′ N., Long. 96° 24′ E.), nearly opposite the village of Pachaung (or Petkyaung).

Impossibility of exploring the country thoroughly in its present state.

In the present state of the country it was impossible to make more than a very superficial examination of the coal, as no supplies were obtainable except from Hlaingdet, a distance of 30 to 40 miles by road, and coolies were unwilling to visit that part of the country. The region is very wild and there are no inhabited villages, all the inhabitants having retired from fear of dacoits, who have harassed them in former years, to the jungles, where they subsist upon such jungle roots, fruits, and other food as they can procure. They were, however, at the time of my visit, recovering from their state of alarm, as the country is now quieter than it has been for years: in some parts they have sown paddy; and the Thugyi of Minpalaung or Membaloung told me that he proposed shortly to rebuild his village and live there again. When the country has settled down, it would be possible to make a closer examination of the coal, though its unhealthiness would always make this a difficult matter; while at least a whole working season would be necessary for the purpose.

Various outcrops of coal.

The coal is exposed in the beds of the streams running into the Panlaung on the right bank, and in the hillsides to the east of the river. I was only able to visit the more accessible of the groups of outcrops, of which the following is a list:—

The Pagamyaungchaung group.
The Mithuichetkyauk group.
The Ingôndaung group.
The Thabyetaungdan group.
The Chobinmyaungchaung group.
The Chobinmyaungmachaung group.
The Chakimyaungchaung group.
The Thaikthaw group.
The Kyatthaungdaung group.
The Kyaulimyaungchaung group.
The Ludwin group.

[1] Journal, A. S. B., XXXI, p. 215.

[2] See map 2.

I travelled from Hlaingdet by Pyinyaung and Taungkubyin to Sôngyi, at the junction of the Myittha and Panlaung rivers. Sôngyi is about 15 miles from Pyinyaung, and the road, though bad, is capable of improvement. From Sôngyi I visited the Pagamyaungchaung and the Mithuichetkyauk. The other localities I visited from Minpalaung.

Outcrops visited.

The Pagamyaungchaung runs into the Panlaung river at a distance of from 4 to 5 miles below Sôngyi. In this stream, which was nearly dry at the time I visited it, there are several exposures of coal.

Pagamyaungchaung outcrops.

The greater part of the rocks seen by following the stream up from its junction with the Panlaung consists of granular limestone, shales, and calcareous conglomerates:—

I.[1]—About $1\frac{1}{2}$ miles up the stream bed the first signs of coal are seen in the form of a bed of dark shales, dipping to the S. W. at 75°, and containing a 2-ft. thick pocket of glistening and much fractured coal, which thins out in a distance of 2 feet to a thickness of 4 inches.

II.—One hundred yards further up the stream, here flowing from N. to S., is another bed of shales, with coal dipping to S. W. at 60°; the following section being exposed:—

	Ft.	In.
1. Granular limestone (thickness not seen)	...	...
2. *Coal*	2	0
3. Carbonaceous shale	9	0
4. *Coal*	2	0
5. Red and white shale	3	0
6. Limestone (not gone through)	...	...
TOTAL	16	0

(Coal 4 ft.)

The coal has a greasy feel, and readily breaks up into small fragments, being traversed by irregular lines of fracture throughout the mass, but some of it would make a good fuel.

Some of the shales contain obscure and indistinct plant impressions.

Further up the stream there are several more smaller seams exposed in the same manner, but none exceeding 2 feet in thickness, and all with the same high dip and unsatisfactory appearance.

The Mithuichetkyauk locality is on a hill about three miles from Sôngyi, on the road to Singulèbyin. The hill overlooks the Panlaung river, and is on the left or west bank and therefore in British territory.

Mithuichetkyauk outcrops.

There are here six exposures displayed on the hillsides, and remains of the old workings are to be seen.

[1] The Roman numerals refer to the Table of Outcrops (see page 187).

III.—In the first exposure the section seen is as follows, the dip being to S. W. at 72°:

Section (a).

	Ft.	In.
1. Sandstone (total thickness not seen)	...	...
2. Dark shale	.	.
3. *Coal*	1	6
4. Shale	2	0
5. Carbonaceous shale	4	0
TOTAL	7	6

(Coal 1 ft. 6 in.)

Signs of this coal are seen in two places along the strike, and 100 feet in the same direction we have the following section :—

Section (b).

	Ft.	In.
1. Sandstone (thickness not seen)	...	...
2. Shale (red and white, and much foliated)	4	0
3. *Coal*	1	6
4. Muddy, clayey shale	0	3
5. *Coal*	1	9
6. Red shale (bottom not seen)	...	...
TOTAL	7	6

(Coal 3 ft.)

This being in the direction of the strike, probably represents to some extent the section (*a*).

Two hundred feet to the dip two more exposures of coal are seen, one only 6 inches in thickness and the other but little better. The following section can be made out at the second exposure :—

	Ft.	In.
1. Shale containing ferruginous nodules (whole thickness not seen).	...	...
2. *Coal*	0	4
3. Dark shale	3	0
4. *Coal*	1	0
5. Red and white clayey shale (whole thickness not seen)	...	...
TOTAL	4	4

(Coal 1 ft. 4 in.)

In No. 4 the *coal* thins out, in a distance of 2 feet, to a mere string, but again increases in thickness to 2 inches further on.

Ingondaung outcrops.

The Ingondaung hill is near Minpalaung, about 2 miles in a south-westerly direction. The path from Minpalaung crosses the Chuadamyaung (or Ye-e) Chaung.

IV.—On the side of the hill towards Minpalaung (N. E.) eight inches of coal are to be seen. The ground has fallen in and concealed the section to a great extent, but the dip is to S.70°W. at 70°, and there is a red clay both above and

below the coal, the upper clay being somewhat shaly. This coal is said to be $2\frac{1}{2}$ cubits thick at a depth of 5 cubits.

V.—A few yards further up the hill, *i.e.*, to S. W., there is another seam dipping S. W. at 40° and only 1 foot 6 inches in thickness; this is also said to increase in thickness lower down, but the thickness is probably to a great extent made up of dark shale. Below the coal there is a brownish shale containing fragmentary plant remains, while above the coal is a white clay, spotted with red.

VI.—A short distance round the hill, towards the S. E. from outcrop No. V, there is a perpendicular band of silicified sandstone, varying in thickness from 2 to 4 inches and running N. W. to S. E. Against this, on the N. E. side, is a soft sandstone, while against the S. W. face is the coal.

The coal is perpendicular, with the same strike as the band of silicified sandstone. The section is exposed in two places, 15 feet apart; in one of the two places only a portion of the section can be seen, as the bank has fallen in and concealed the remainder, but the siliceous band and finely jointed shales give points from which they can be compared.

Sections.

1. Finely and irregularly jointed dark grey shales, common to both (*a*) and (*b*).

2 (*a*)

	Ft.	In.
1. Brown clay . .	0	1
2. *Coal*	0	3
3. Clay, with coaly matter	0	5
4. *Coal*	0	5
5. Clay, with coaly matter	0	7
6. Concealed; said to consist of *coal* . .	5	3
TOTAL .	7	0

15 feet interval.

(*b*)

	Ft.	In.
1. *Coal*	1	6
2. Coaly matter . .	0	1
3. *Coal*	0	3
TOTAL .	1	10

3 Band of siliceous sandstone common to both (*a*) and (*b*).

Here we have evidence of the extreme irregularity of these beds, for what is in one place 7 feet, with 8 inches (or 5 feet 11 inches according to report) of coal, is reduced, at a distance of 15 feet, to 1 foot 10 inches, with 1 foot 9 inches of coal.

The coal is also much broken and very finely jointed.

VII.—About quarter mile to S. E. of outcrop No. VI there is another outcrop striking north-south, and also perpendicular at the eastern end of the section, while at the western end the dip is to S. W. at 80°:—

Section..

		Ft.	In.
W.	1. Shale, finely jointed, black (thickness not seen)	...	...
	2. *Coal*	1	6
	3. Shale (same as No. 1)	5	0
	4. *Coal*	0	6
	5. Shale (same as Nos. 1 and 3)	1	0
E.	6. Coal (much crushed)	0	6
	TOTAL .	8	6

(Coal 3 ft.)

This coal is said to burn like oak, while the others burn like jungle-wood. This section is a good example of the extremely disturbed condition of the beds, for we have a difference of 45° in the direction, and of 10° in the amount of dip, in a thickness of 8 feet 6 inches.

Thabyetaungdan outcrops.

VIII.—About one mile from No. VII, on a portion of the hill known as the Thabyetaungdan, there is an outcrop containing 7 feet 6 inches of coal at the thickest portion and divided into two layers by 5 feet of clay and shale. The dip is here 60° to W. 20°N.

Section.

	Ft.	In.
1. Surface soil	...	...
2. *Coal*	2	0
3. Red and white clay	2	0
4. Usual jointed shale	3	0
5. *Coal*	5	6
6. Shale (not gone through)	...	...
TOTAL	12	6

(Coal 7 ft 6 in.)

This seam is seen again a few yards along the strike to N.20°W., but here only 4 feet of coal are to be seen. This coal is of the same quality as the rest, and there appears to be the same irregularity of thickness; and, although the dip at this point is not so high as in other parts, no reliance can be placed on this where there is so much disturbance among the rocks. In the immediate neighbourhood there are signs of numerous small excavations where the coal was formerly dug.

This is, however, the most promising of all the outcrops I saw; and it is here, if anywhere, that I should recommend explorations to be carried out, though I very much doubt their being successful. Owing to the high dip, 60°, it would be necessary to explore by driving an inclined shaft in the coal which would show whether it remains constant in thickness and quality.

IX.—Close to No. VIII there is another locality, which is chiefly interesting on account of the occurrence of fairly perfect fossil plant remains, which appear to be of tertiary age. This was the only place in which I found fossils in anything but a very fragmentary condition: they occur in a bed of clayey shale on the south side o the coal, which is here again perpendicular.

Section.

	Ft.	In.
1. Clayey shale	4	0
2. *Coal*	0	2
3. Shale	0	2
4. *Coal*	2	0
5. Earthy shale	0	2
6. *Coal*	1	0
7. Shale	0	6
8. Inferior shaly coal	1	0
9. Shale (total thickness not seen)	...	...
TOTAL		

(Coal 3 feet 2 inches.)

Another outcrop containing coal occurs on the Thabyetaungdan, but it is very intimately mixed with a clayey shale, there being about 6 feet of coal and clayey shale in alternating bands of about 6 inches in each.

There are said to be many other outcrops of coal on the Thabyetaungdan, but they are probably inferior to those I saw, which were the ones formerly worked, for which purpose the thickest seams would naturally be selected.

Chobinmyaungchaung outcrops.

X. In the Chobinmyaungchaung, which is a small stream running into the Panlaung river, the following section is seen :—

	Ft.	In.	
1. *Coal*	1	6	Dip S.40°W. 90°
2. Shale, containing a pocket of coal 6 feet long by 6 inches thick . . .	3	0	
3. Nodular ferruginous clay . . .	0	3	
4. Shale	0	3	
5. *Coal*	1	0	
6. Dark, jointed shale	2	2	
7. Hardened clay band	2	8	
8. Dark shale (same as No. 6) . . .	1	4	
9. Hardened clay band	0	1 to 2 inches.	
10. Shale (same as No. 6) . . .	5	0	
11. Clay band (same as No. 7) . . .	1	6	
12. Shale (same as No. 6) . . .	8	0	
13. Clay band (same as No. 7) . . .	0	5	
14. Shale (same as No. 6) . . .	4	0	
15. *Coal*	2	0	
16. Shale (same as No. 6) . . .	3	0	
17. Clay band (same as No. 7) . . .	0	4	
18. Shale containing four hard bands .	8	0	
19. Shale, with streaks of coaly matter .	1	0	
20. Shale (same as No. 6) . . .	3	0	
21. Clay band (same as No. 7) . . .	2	0	
22. Light coloured sandy shale . .	3	6	
23. Hard clay band (same as No. 7) . .	12	0	Dip, S. 30° W. 90°
TOTAL .	66		

(Coal 4 feet 6 inches.)

The direction of the strike here alters 10° in a thickness of 66 feet. There is only a total thickness of coal of 4-ft. 6-in. in three bands. The continuation of the section was formerly exposed lower down the stream and coal worked there, but the bank has now fallen in and concealed the exposure.

XI.—In the Chobinmyaungmachaung, a small stream which runs into the Chobinmyaungchaung, there is a mass of the usual jointed black shales containing several pockets of very shaly coal of no great size. The dip is here to S. 65° W. at 50°.

Chakimyaung outcrops.

At distance of one to one-and-a-half miles from Minpalaung, in a westerly to north-westerly direction, is a small stream called the Chakimyaungchaung, in which some coal (XII) is exposed.

The coal is inferior in appearance and only 2-ft. in thickness. The dip is to S. W. at 75° :—

Section.

		Ft.	In.
1. Clayey jointed shale	Over	10	0
2. Inferior laminated *coal*		2	0
3. Laminated shale		1	0
4. Jointed brown shale		2	0
5. Coaly shale		0	5
6. Laminated shale (only a few feet seen)		...	...
TOTAL		15	5

(Coal 2 feet.)

At Thaikthaw there used to be an exposure of coal which was worked, but the bank has fallen in and concealed it. The shale just here contains nodules of iron pyrites which are used for the manufacture of sulphur.

Thaikthaw outcrop.

XIII.—A few yards further up the stream than the old workings a small section containing coal is seen :—

	Ft.	In.
1. *Coal*	1	0
2. Black, jointed shales	4	0
3. *Coal*	1	0
TOTAL	6	0

(Coal 2 feet.)

Above and below this section is the usual black, jointed shale. The beds are here perpendicular and strike S. 20° E., but 20 yards to the east the finely jointed shales are seen dipping to S. 70°, W. at 60°. At a distance of 100 yards to the north-west of this point, in the jungle, there is an outcrop of 6 inches of coal smut.

XIV. In a stream on the Kyatthaungdaung there is a small outcrop of coal which is only 2-ft. thick, and very much broken and irregularly laminated. It lies between bands of shale, and the dip is to N. W. at 30°.

Kyatthaungdaung outcrops.

Just above this, in the same stream, there is a well exposed section (*XV*), with a dip to W. of 26° :—

	Ft.	In.
1. Shale; top not seen	...	...
2. Pocket of *coal* in shale	2	0
3. Shale with strings and small pockets of coal	11	0
4. Pocket of *coal*, thinning out in a short distance	0	5
5. Shale, black, jointed	3	0
6. Hardened clay band	0	4
7. Much contorted *coal*	2	0
8. Shale, containing a few strings of coaly matter	20	0
9. Much disturbed *coal*	4	0
10. Much contorted band of shale, containing strings of coaly matter	6	0
11. Finely laminated and jointed shale	2	0
12. Band of bright *coal* (thins out rapidly)	1	6
13. Black shale (same as No. 11)	3	0
14. Band of ferruginous hard clay	2	0
TOTAL	57	3

(Coal 9 feet 11 inches.)

The total thickness of the coal seen here is 9 feet 11 inches, but 3 feet 11 inches of this is in the form of evanescent bands or pockets, while the remaining 6 feet is divided into two portions of 2 feet and 4 feet respectively, separated by 20 feet of shale, besides which the coal is much crushed and contorted.

XVI.—A few yards to the N.W. of No. *XV* is another section containing coal, with a dip to S.W. of 70°—

	Ft.	In.
1. Much contorted black shale (thickness not seen)	...	...
2. Much contorted *coal*	2	0
Here a small fault runs across the section from N. to S.	...	...
3. Grey, slightly ferruginous shale	4	0
4. *Coal* laminated and contorted	2	0
5. Ferruginous, hard, clayey shale	1	0
6. Black, jointed shale	20	0
7. *Coal* . . . Over	2	0
Remainder concealed	...	...
TOTAL	31	0

(Coal over 4 feet.)

These two sections give another example of the extremely disturbed condition of the beds, for we have them at two spots, less than 50 yards apart, dipping to S.W. at 70° and to W. at 26°, and the beds are seen in the section to be greatly disturbed and contorted.

Two hundred yards to the north of this last section, a small outcrop of coal is badly exposed, and a quarter of a mile to S.W. of this, another section (*XVII*) is seen, though it is badly exposed, in the bank of the stream. The uppermost 30 feet are concealed by the bank having fallen, but there is apparently a small amount of coal there, and some shale can be seen: below this some more coal can be seen. The dip is 60° to S. W.—

Section.

	Ft.	In.
1. Concealed: probably shale	30	0
2. Much contorted and irregularly bedded carbonaceous shale	4	0
3. *Coal*	1	6

The exposure continues with the same dip for about 50 yards down stream, and then a small pocket of coal is seen in the carbonaceous shale.

Kyaulimyaung outcrops.

XVIII.—In the Kyaulimyaungchaung there is a small seam of coal dipping 60° to E. between beds of yellow shale. The coal is very friable and irregularly fractured.

Ludwin outcrop.

The last locality I saw is situated to the north of Minpalaung and is known as the Ludwin. Coal is said to have been formerly worked here in a perpendicular seam; but the hole is now filled up, and all I was able to see was a perpendicular bed of dark shales.

Coal formerly worked.

Coal is said to have been extracted at all these localities in King Mindôn's time, and sent down to the Irrawaddy for use at the Sagaing iron-works. The works were all surface quarries, and one or more men worked at each exposure of coal, receiving R8 for each 100 baskets dug out. The coal cost another R16 to transport to the Irrawaddy; on pack-bullocks as far as the Panlaung, and the rest of the distance on bamboo rafts. The price realized, when sold to outsiders on the Irrawaddy, is said to have been R1 per basket.

No prospect of working the coal profitably.

I did not see a single seam which held out any real prospect of being workable. The seams are exceedingly irregular; that is to say, they are not to be depended upon to extend to any distance. A large proportion of the coal consists of mere pockets; and even where this is not immediately evident, and they can be traced for any distance, they are found either to thin out altogether or to decrease considerably in thickness.

Another point which is greatly against the coal is the very large amount of disturbance to which the strata have been subjected. The beds have been tilted up at very high angles and are often perpendicular. There must be a considerable amount of faulting associated with the extreme contortion which the beds have undergone, and the coal has been in many places so much crushed as to make it impossible to extract any but the smallest fragments.

The accompanying table (Table I) shows the variety and high inclination of dips over the area which I visited.[1]

It will be seen that, even omitting the exceptional cases, *XIV* and *XVIII*, the direction of dip varies from S. to W., and the angle from 26° to 90°. It will be readily imagined what a deleterious effect the crushing following on these movements must have had upon the quality of the coal as regards its capacity for being extracted in suitable lumps. Even if the coal were uninjured, the high angles of the dips, and their great irregularity, as pointed out in several cases above, would preclude all possibility of working it at a profit.

As far as I saw, the only place where there is any reasonable chance of the coal being workable, is at the section (No. *VIII*) on the Thabyetaungdan; and if nothing better should be found further north, where there is said to be more coal, it might be worth the while of Government to explore this seam, as advised above.

Area over which the coal occurs.

The coal occurs over an area of 150 to 200 square miles, and within the limits of each group of outcrops the seams are thickly distributed, though they never attain any large size without a large proportion of shale partings, and frequently thin out within a short distance.

Age of the coal.

It appears to be of tertiary age, and there can be little doubt that explorations would reveal more completely the irregular and variable characters so well known in the tertiary coals, and which have been so well exemplified at Thayetmyo. At Thayetmyo the position of the

[1] In order to avoid confusion by introducing the strike of the beds, I have preferred, in cases where the beds are perpendicular, to consider them as dipping 90° in the direction at right angles to the strike nearest approximating to the average direction of dip of the district (= about S. 66° W.).

coal formed an inducement for endeavouring to work it; but here on the Panlaung the difficulties of transport would be so great that, unless an exceptionally good seam were discovered, it would be cheaper to obtain coal for the railway from Rangoon.

Coal assays.

The results of assays of the coal carried out in the Geological Survey laboratory by Mr. T. R. Blyth are very satisfactory, the ash being in most cases very low. A remarkable feature about these coals is the low percentage of volatile matter, which is due to the great disturbance which the coal has undergone. This would influence the burning of the coal to great extent by reducing the amount of flame, and it would therefore be unfitted for furnaces, in which much flame is required.

The table of assays will be found below.

Only one practicable method of working the coal.

I believe that the only means by which it would be possible to work the coal would be that used when it was formerly worked. Then each outcrop was quarried by one or more workmen, and the resulting fuel collected at various points for shipment upon rafts. The irregularity, uncertain thickness, and high dip of the seams would preclude the possibility of working by the ordinary methods of coal-mining.

Means of transit.

As regards means of transit, I was unfortunately unable to obtain the help of Mr. Bagley to go over the ground, as he was unable to leave other work at the time, but I imagine that it would be a very expensive undertaking to make a tram-line up to the coal-field from any point on the Toungoo-Mandalay Railway south of Kyauksè. At least 20 miles would have to be laid even if it could be done in a straight line, which would be impracticable on account of the hills to be crossed; and by no amount of deviation would it be possible to avoid the hilly ground altogether.

Though I have not seen the country to the north, I am inclined to think that the best line would be from the neighbourhood of Kyauksè up the valley of the Panlaung, though this would probably present such engineering difficulties as to make the line very expensive, and the portions of the coal-field which I have explored are not worth it.

Labour at hand.

At present the labour at hand is scarce, and would have to be imported from Hlaingdet or the direction of Nyaungywe. The disposition of such of the people as I saw was decidedly friendly, but they were very timid, and I doubt whether I should have seen any of them if Maung Sein Bôn, who was in charge of the coal workings in King Mindon's time, and whom they knew well, had not been with me.

Coal in Ywangan territory.

The coal is almost all in Ywangan territory, and, as I do not know what the relations of Government are with the ruler of Ywangan, I am unable to give any opinion as to his claims or rights. It would not be worth while for Government to work the coal at present, and I doubt whether any outside parties would care to take the matter up. But after a few years, when the country is settled, the whole coal-field should be examined, and any seams, such as the one on the Thabyetaungdan (No. *VIII*), which give any hopes of successful working, should be further explored.

TABLE I.—*Showing the chief Outcrops referred to.*

No.	LOCALITY.	Direction of dip.	Angle of dip.	Thickness of coal. Ft. In.	REMARKS.
I	Pagamyaungchaung .	S. 45° W.	75°	2 0	A mere pocket of coal.
II	Ditto . .	S. 45° W	60°	4 0	There is a 9-ft. parting of shale between the two layers of coal, making up this 4 feet.
III	Mithuichetkyauk . .	S. 45° W.	72°	3 3	This thins down in a short distance to 1 foot 6 inches, and there are two other layers of coal near, 1 foot 4 inches, and 6 inches respectively.
IV	Ingôndaung . . .	S. 70° W.	70°	0 8	
V	Ditto . . .	S. 45° W.	40°	1 6	
VI	Ditto . . .	S. 45° W.	90°	6 0	It is doubtful whether this coal is really as thick, and 15 feet off, it is only 1 foot 9 inches.
VII	Ditto { East end .	S.	90°	3 0	Much crushed and in three layers, separated by 6 feet of shale partings.
	Ditto { West end .	S. 45° W.	80°		
VIII	Thabyetaungdan . .	W. 20° N.	60°	7 6	In two layers of 2 feet and 5 feet 6 inches, separated by shale and clay. (This is the most hopeful locality I saw.)
IX	Ditto . . .	S.	90°	4 2	With shale partings. The lowest 1 foot is very inferior.
X	Chobinmyaungchaung .	S. 40° W.	90°	4 6	Opposite ends of the same section.
Xa	Ditto ditto . .	S. 30° W.	90°		
XI	Chobinmyaungmachaung	S. 65° W.	50°	...	Pockets of shaly coal.
XII	Chakimyaungchaung .	S. 45° W.	75°	2 0	Very inferior.
XIII	Thaikthaw . . .	S. 70° W.	90°	2 0	With a 4-ft. parting of shale
XIV	Kyatthaungdaung . .	W. 45° N.	60°	2 0	Twenty yards to east of XIII, irregularly laminated.
XV	Ditto . . .	W.	26°	9 11	2 feet 5 inches and 1 foot 6 inches consist of pockets of coal, the remainder, 4 feet and 2 feet, is much disturbed.
XVI	Ditto . . .	S. 45° W.	70°	6 0	This is much disturbed, and there is a fault in the section.
XVII	Near Kyatthaungdaung .	S. 45° W.	60°	1 6	There is, in addition to this, a small pocket lower down the stream.
XVIII	Kyaulimyaungchaung .	E.	60°	...	Covered by yellow clay.

TABLE II.—*Results of Assays of some Coals from the Panlaung Coal-field.*

	Pagamyaung-chaung.	Mithuichet-kyauk.	Kyatthaung-daung.	Ingôndaung.	Ingôndaung, Thabyetaung-dan.	Chobinmyaung-chaung.	Chobinmyaung-chaung.	Chobinmyaung-chaung.
	II	III	XIV	VI	VIII	X (1)	X (5)	X (15)
Moisture . .	1·36	15·46	2·82	2·18	2·90	3·04	4·50	2·28
Volatile matter, exclusive of moisture.	14·32	28·48	11·12	18·82	9·18	14·92	30·78	7·26
Fixed carbon .	78·80	50·94	63·16	76·00	73·02	62·18	62·38	60·00
Ash . .	5·52	5·12	22·90	3·00	14·90	19·86	2·34	30·46
TOTAL .	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Sinters slightly. Ash, dark reddish brown.	Does not cake. Ash, light yellowish grey.	Does not cake. Ash, light grey.	Does not cake. Ash, light brown.	Does not cake. Ash, light grey.	Sinters slightly. Ash, light grey.	Cakes but not strongly. Ash, light brown.	Does not cake. Ash, very light grey.

3.—TWO COAL LOCALITIES IN THE SHAN HILLS.[1]

Lègaung near Singulèbyin.—I was informed of the occurrence of this coal by the Lônpan Thugyi, who accompanied me from Singu to the place where the coal is to be seen. Lègaung is a small village, about 4 miles from Singu in a southerly direction.

Close to the village of Lègaung, on the road to Kyat Sakan, coal is seen in two places. In the first very little is visible, but it had been exposed by digging, and I was able to make out the following section :—

	Ft.	In.
1. Surface soil	..	...
2. Coal smut	0	4
3. Brown clay	0	9
4. Coal smut	0	2
5. Brown clay	0	6
6. Coal smut	0	1
7. White clay	0	1
8. Powdery coal	0	4
9. White clay; not gone through . . .	...	...
TOTAL .	2	3

[1] See map 2.

A few yards further on, 3 feet of very powdery coal is seen topped by surface clay and dipping to W. at 40°. It does not look at all promising, nor does there seem to be any chance of its improving to the deep. From the rocks occurring in the neighbourhood it would seem that this coal is like that of the Panlaung of tertiary age.

At about one mile from Lègaung is the deserted village of Titpalwiywa, close to which, in a small, dry water-course, is a coal locality known as Titpalwigôn. Here there are $1\frac{1}{2}$ feet of fair coal between beds of dark grey shale; about 3 feet below the $1\frac{1}{2}$ feet of coal is another foot, but it is not well seen. No other coal is seen in the immediate neighbourhood, and there is no prospect of this being workable. This is also tertiary coal.

Ngu, near Pwehla.—This coal was brought to my notice by Maung Sein Bôn on my return from Fort Stedman, and is situated about 7 to 9 miles north-west of Pwehla on a hill lying about a quarter of a mile from the village of Ngu.

The coal is found in three places on the hill. In the first it is 11 feet thick and dips to the west at 70°; it rests on clayey shale, and contains a great deal of clayey matter and is very soft. It also contains a large quantity of iron pyrites, which is picked out for use in the manufacture of sulphur. In the second exposure, which appears to be a part of the same seam, the coal is perpendicular and, at the level of the water in the stream in which it is exposed, is 7 feet thick, but 20 feet above, it is only 4 feet thick. This is also very clayey, though it contains no pyrites, and it occurs between bands of hard silicified sandstone. The third spot, which I did not visit, is higher up the hill, and the coal there is said to be inferior to that in the other two localities, though it is more valued on account of its containing a larger proportion of pyrites. This is also of tertiary age, though it can hardly be called coal, being rather a carbonaceous shale, as may be seen by an inspection of the results of assays by Mr. T. R. Blyth, a table of which is appended—

	NGU COAL-FIELD.		LEGAUNG COAL-FIELD.	
	From perpendicular outcrop, Ngu.	Ngu, 11-ft. seam.	Titpalwigôn, near Lègaung.	Lègaung.
Moisture	3·08	2·74	2·02	2·14
Other volatile matter	4·00	6·48	12·94	12·06
Fixed carbon	4·62	17·14	72·54	68·32
Ash	88·30	73·64	12·50	17·48
TOTAL	100·00	100·00	100·00	100·00
	Does not cake. Ash, very light grey.	Does not cake. Ash, very light brownish grey.	Does not cake. Ash, reddish grey.	Does not cake. Ash, reddish grey.

From these assays it is evident that this substance is useless as a fuel.

As regards the Lègaung coal, it would make a fair fuel, though the volatile matter is very low, as in all these coals.

4.—ON LIGNITE OCCURRING AT THIGYIT, NEAR NYAUNGWE.[1]

Having been informed that coal was reported by Mr. Scott to exist at Thigyit, near Fort Stedman, and the coal of the Panlaung field not proving so good as was expected, I determined to take the opportunity of being in the neighbourhood to visit the locality.

After much delay I left Fort Stedman accompanied by the Myoôk of Thigyit. Thigyit is situated about 11 to 12 miles due west of Indeinmyo, at the south end of the Nyaungywe lake. The road from Indein is fairly good, but passes over two ranges of hills, and it would hardly be practicable during the rains. The rocks are of the usual character, exposed in this part of the country, namely, massive limestones with red and pink shaly clays and conglomerates.

The so-called coal is situated 2½ to 3 miles to the south of Thigyit, on the road to Mobyè and Rangoon. At this point a small stream, known as the Mithui Chaung, runs across the road, and close by there is a phoongyi kyaung called the Mithui kyaung.

The black substance here exposed, which had given rise to the report of coal, is not true coal, but lignite or brown coal, and though superficially there appears to be a large seam, this, as is seen when it is dug into, is not the case. The lignite can be traced at intervals for a distance of quarter of a mile up the stream from the bridge where the road crosses. The dip of the masses of lignite varies from 15° to 45° to N. W. There are about twenty exposures, some of which are 2 to 3 feet in thickness, and in one case 6 feet. The lignite alternates with grey, yellow, and brown clay.

By digging at a point above the bridge, where one of the 3-ft. layers is exposed dipping to N. W. at 15°, I was able to see the very delusive and irregular character of the deposit, for what looked like a good seam at the surface was found to consist, a few feet below, of—

	Ft.
Clay and surface soil	
Lignite . .	2
Brown clay .	2
Lignite . .	2
Brown clay .	4
Very brown clay not gone through.	

The lignite is of a plastic nature, containing fragments of fossilized wood, which is also found in the brown clay. The clay contains numerous fossil shells, the larger ones very much crushed: they are evidently of recent origin, and some of the smaller ones, when extracted from the clay, will probably be recognizable, though, owing to their brittle nature, this could not be done in the field.

The whole appearance of this deposit shows that it is the bottom of an old lake, which has silted up in recent times in the same way as the Nyaungywe lake is doing at the present time; and this deposit of lignite is the remains of the plants

[1] See map 2.

which grew there at the time, and of the logs of wood carried into the lake. The conditions are very favourable for the filling up of lakes among these hills, as large quantities of clay are brought down by the streams during the rains: the Nyaungywe lake can be seen to be filling up very fast, and near the banks, especially near the points where streams fall into it and form deltas, it is little more than a bog.

There is no hope of obtaining any large or profitable supply of fuel from this source, though it might well be used for local purposes should any demand arise for small quantities. The supply would always be precarious.

Appended is the result of an assay of some of this lignite by Mr. T. R. Blyth in the Survey laboratory. The high percentage of moisture is characteristic of lignite. From the assay it will be seen that the lignite contains only 66·48 per cent. of combustible matter:

Post-tertiary Lignite from near Thigyit.

Moisture	22·74
Other volatile matter	36·26
Fixed carbon	30·22
Ash	10·78
TOTAL	100·00

Does not cake. Ash brown.

5.—ON THE METALLIFEROUS MINES IN THE NEIGHBOURHOOD OF KYAUKTAT AND PYINYAUNG IN THE SHAN HILLS.[1]

Argentiferous galena near Bawzain.

Silver-lead Mines of Kyauktat and Bawzain.—Bawzain is a small village in the neighbourhood of Kyauktat, near Pwehla. About 1½ miles to the north-east of the village there is a valley among the hills, the bottom of which is filled with red clay, the rocks of the surrounding hills consisting of limestone. In clefts in the limestone, and below the red clay, a yellow, somewhat calcareous clay, occurs containing the argentiferous galena. The ore is said to occur in blocks and fragments, varying in size from 3 feet across to the size of a pea. I was unable to enter the mines, most of them having been closed for three years, owing to the disturbances in the country; and of the two that had been recently worked, one had been recently abandoned on account of its unsafe condition, while the other, being only worked during the dry weather, had been closed for the rains.

The larger lumps, which are of too great a size to be readily carried out of the mine, are broken up and brought out with the smaller lumps and the clay in which they occur, and the whole is washed by means of water, which, while removing the clay, leaves the heavier fragments of ore behind. The ore is then collected in baskets and removed to one of the smelting-houses in the neighbourhood. The ore is said always to occur in this manner, imbedded in the yellow clay; and when it occurs in a cleft or fissure of the rock the walls of the cavity are frequently lined with crystalline calcite.

[1] See map 2.

When the ore occurs in a fissure of the rock, a passage is driven along in the clay between the walls of the fissure, which is usually very tortuous and irregular in its course. The mouth of one of these tunnels which I saw was about 3 feet high and 2 feet wide, and running towards north-west at about 45°, though just beyond the entrance it gets narrower and steeper. The whole length of the passage is said to be 300 cubits. Where the ore occurs below the red clay in the bottom of the valley, square shafts, inclined at about 70°, are dug through the red clay, steps being cut till the yellow clay is reached, which is said to be at a depth varying from 50 to 150 cubits. Chambers, as large as the fear of subsidence of the roof will allow, are then excavated in the ore-bearing clay which is removed and carried to the surface. When it is considerd too dangerous to remove any more clay, the place is abandoned and a new shaft put down at a short distance off. Frequently, if not always, one chamber communicates with the air by means of at least two shafts.

Smelting the ore.

Two baskets full of the ore are smelted at a time, the first operation being carried out in a small blast-furnace heated with a charcoal fire.

The blast is produced by means of a pair of bamboo bellows, which deliver the air through a pair of earthenware tuyères at the back of the furnace. There is also an opening below in front, through which the molten lead is manipulated, and which can be closed at the pleasure of the operator. The lumps of ore without previous calcination are put into the furnace with charcoal, and ore and charcoal are added from time to time; and the molten lead drops down into a hollow below, from which it is ladled out into moulds. A large proportion of lead remains in the dark-coloured glassy slag, which is produced, and no steps appear to be taken to recover this; while the only use that is made of the slag is as glass for the manufacture of ornaments. I did not see this furnace at work, but gathered the information through my interpreter from the smelter.

The operation of reducing the two baskets-full occupies a whole day, and the result is ten hemispherical pigs of metal, averaging about 16℔ in weight.

These pigs are then removed to a hut close by, where they undergo the operation of cupellation. The furnace used consists of a basin-shaped cavity in which the molten lead lies, over which the fire of logs of charcoal is supported, so that the heating is by radiation from above. The furnace is closed in at the sides, back, and top, and there is no chimney. In front there are two openings, one a large one just above the surface of the molten lead, and a smaller one above, through which the fire is manipulated.

When the lead is all melted, it gradually oxidizes, and the litharge floating on the surface of the molten lead is drawn off by thrusting an iron rod through the lower opening and rotating it in the litharge which clings to it; and by repeating the operation a ball is collected on the end of the rod, which is knocked off and a fresh one collected. This operation is repeated till most of the lead has been oxidised, when charcoal ashes are thrown in to absorb the remainder of the litharge formed, and the fire kept up till a button of silver is formed. The button, which I obtained, and which was said to be the result of the cupellation of ten pigs, weighs nearly five tolas, and the usual result is said to be from four to six tolas.

There are two furnaces, built together side by side, which are used alternately.

Below the furnace is an opening, through which the bed of the furnace can be broken up and removed when it becomes saturated with litharge.

This operation is also said to last about one day; but, as there is very little draught owing to the absence of chimney, the products of combustion being carried off through the upper opening, this must be a considerable waste of time.

The silver is not refined any more, but sold in buttons, the price being, according to my informant, 8 annas per tola of rough silver.

The balls of litharge obtained are taken back to the blast-furnace in which the first operation is performed, and there reduced again by the help of a charcoal fire in the same manner as in the first operation. No provision is in any case made for condensation of the lead fumes, and the loss, both in lead and silver, must be very great. The resulting lead in ten pigs probably weighs about 120lb. I was told 400 viss, but, as only ten are formed, and the one I obtained only weighs 18lb., this is manifestly absurd, and the error probably resulted from the interpreter's very limited knowledge of English. The total profit to the furnace proprietor, who does not work himself but employs a smelter, is said to be about R4 per every two baskets of ore smelted.

Galena at Bwèlôn.

Bwèlôn is a village about 4 miles from Bawzain in the direction of Kyauktat. At a distance of about three-fourths of a mile in a north-east direction from this village is a hill, which is ramified by old workings, some of which are said to run right through from one side of the hill to the other. The argentiferous galena occurs here in the same manner as at Bawzain, in yellow clay in fissures of the limestone rocks. The ore here is, however, richer in silver than that of Bawzain; it is said to give eight tolas of silver to two baskets of ore.

Argentiferous galena at Dwinzu.

Dwinzu is about half-way from Bwèlôn to Kyauktat. It is merely the name of the locality (there being no village in the immediate neighbourhood), which is situated on the banks of the Ngaboi Chaung.

The ore occurs here in the river-bed in the form of pebbles and in a fissure close to the stream. It is said to give 25 to 30 tolas of silver to two baskets of ore, but is not so plentiful as at the other two localities.

Work at the mines stopped.

No work has been carried on either at Bwèlôn or Dwinzu for some years now, but at Bawzain two of the mines had been worked up to a short time before my visit. The Ngwegunhmu, or hereditary ruler, charges a royalty of R1 per month for every man and wife working in the mines and takes one-third of the ore. Kyauktat was visited by the Salween Expedition in 1864-65, and a description of the manner of smelting the ore is given by Mr. F. Fedden in his report on the expedition.[1] He was, however, unable to visit the mines. This source of lead and silver is also mentioned in Captain G. A. Strover's memorandum.[2] I was able to procure enough of the Bawzain ore to furnish an assay, and the result shows 74·29 per cent. lead and 13 ozs. 7 dwt. 20 grs. of silver to the ton of ore by dry assay, and a trace of gold. This would hardly pay to work systematically at the present low price of silver.

[1] Sel., Records, Govt. of India, Vol. XLIX, p. 39.

[2] Reprinted from the *Gazette of India* in the *Indian Econ mist,* Vol. V.

Galena at Pindaya.

Argentiferous galena is also said to occur in the hills near Pindaya, but is not worked on account of the small quantity of silver contained.

Pyrites near Bawzain and Kyauktat.—About 5 to 6 miles along the road from Pwèhla towards Bawzain, the road passes close to a large stream bed (Thaingyi-chaung), in which is an exposure of dark grey shales. These shales contain a considerable quantity of nodular iron pyrites, which is collected and subjected to distillation in earthenware retorts, in order to obtain sulphur. There seems to have been a considerable amount of sulphur manufactured near Bawzain in former years, but at present all work is stopped. The sulphur is chiefly used in the manufacture of gunpowder.

Pyrites in the Thaingyi-chaung.

About 1½ miles nearer Bawzain is the Thingèchaung where pyrites again occurs in dark grey shales, and is said to be of the same quality as that of Thaingyi-chaung, but less sparingly distributed.

Pyrites in the Thingè-chaung.

Pyrites near Kyauktat.

Pyrites of the same character also exists near Kyauktat, but I was unable to visit the locality.

Miscellaneous Minerals, &c.—At Kyauktat copper, in the form of green carbonate, associated with quartz, occurs, and is said to yield 5 viss of copper to the two baskets of ore. I was unable to visit this locality.

Copper at Kyauktat.

Near Pyinyaung, at Taunglèbyin, on the road from Shwenaungbu to the Shan States, copper ore is said to occur. In some blocks of red serpentine which were brought me from this locality there are some specks of green carbonate of copper.

Copper at Taunglèbyin.

Gold is also said to be obtained by washing in a stream near Taunglèbyin. I tried to visit this locality, but was unable to do so, as it was too far to get there and back to Pyinyaung in one day, and I was unable to procure coolies.

Gold at Taunglèbyin.

Boring Exploration *in the* Chhattisgarh Coal-fields. (*Second Notice.*) *By* William King, B.A., D.Sc., *Director, Geological Survey of India.*

In my previous notice[1] it was shown that, owing to the poor quality of the coal from the boring assays in the Rampur field, examination should be diverted to the Mand Valley, and, if possible in the time at our disposal, to the Korba country also. These later explorations have been made, with, however, no better success.

Tumidih on the Mand River.—Work was begun, under the most unfavourable circumstances[2] near Tumidih in the Raigarh State, about 20 miles N. W. of Rai-

[1] Records, G. S. I., XIX, p. 210.

[2] Following on the death of the Mining Assistant, Mr. Stewart, and the impossibility of replacing him on short notice by a sufficiently competent man, I and my Sub-Assistant, Babu Hira Lal, had in fact to overlook the work.

garh; one of the bore holes (No. 2) entering almost immediately into carbonaceous shales through which it passed at first for some 25 feet, and then again for 20 feet more, but without striking any trace of proper coal. While this was going on, Babu Hira Lal was successful in finding outcrops of coal in the small Pasana or Pasang stream, a short distance to the south, and likewise in the Nagoi tributary, 2 miles to the north of our centre of operations: and thus it was ascertained that we were here on an anticlinal, or flat-arched arrangement of the strata, into the lowest beds of which the two Tumidih bore holes were being sunk, the outcrops exposed in the *nalas* to north and south being in higher beds. Our attention was then directed entirely to the Pasana part of the field: and our hopes were high, for the outcrop showed, at any rate, one band of good-looking coal at least 13 feet thick, out of which, though it was somewhat variable in quality, some 4 or 5 feet of useful fuel might eventually be obtained.

The boring samples as they came up even looked tolerably fair: still there was a suspicious uniformity about them which tallied too closely with those obtained from the other fields, and the old fear of deteriorated samples again became dominant in my mind. These eventually gave such a large percentage of ash that, had it not been for the fair promise of the outcrop, the borings should have been given up at once.

There was nothing for it, then, but to dig well into the outcrop and check the boring samples by comparison with a fair selection of outcrop samples. These were assayed by Hira Lal on the spot;[1] and another series was subsequently tried in the Survey laboratory. There is no use in giving the assays of the bore samples; they were altogether poorer than those from the outcrop, the laboratory assays of which show sufficiently the quality of the coal.

[1] I cannot but record my approval of the willing and workmanlike way of Hira Lal in making these assays at the boring smithy. I have heard complaints of other Sub-Assistants on the Survey objecting to buckle to handiwork which every officer is necessarily obliged to undertake at times; but there was none of this in Hira Lal: on the contrary, he was full of resources, and I have little doubt would have made the clay crucibles had we failed to find them ready at hand in the shape of the little cups used for illuminations.

Outcrop of Coal from Pasana stream, Raigarh State:—Hira Lal seam.

	1st foot.	2nd foot.	3rd foot.	4th foot.	5th foot.	6th foot.	7th foot.	8th foot.	9th foot.	10th foot.	11th foot.	12th foot.	13th foot.	Average of 1st to 13th foot.
Moisture	6·70	4·02	2·54	2·62	4·98	5·20	4·98	3·74	8·36	6·42	5·50	2·58	4·34	4·77
Volatile matter, exclusive of moisture	31·82	24·32	18·36	22·20	24·72	26·24	24·72	20·06	28·56	29·66	27·52	25·02	28·66	25·53
Fixed carbon	44·54	35·40	19·74	27·68	36·58	39·32	30·98	26·18	51·12	44·28	36·96	20·40	31·30	34·20
Ash	16·94	36·26	59·36	47·50	33·72	29·24	39·32	50·02	11·96	19·64	30·02	52·00	35·70	35·50
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Ash, light reddish brown. Does not cake.	Ash, gray. Does not cake.												

This coal is quite unfit for railway purposes; the 1st and 9th foot, in a thickness of thirteen feet, being alone up to the standard of average Indian coal.

The boring also showed a higher seam than that just described, its outcrop, if any, being concealed under the water and sand of stream. Samples of 19 feet of this from the borings were assayed in the laboratory with the following result:—

Samples of Coal from Seam in No. 3 Bore-hole, Pasana River, Mand Valley.

DEPTHS IN BORE-HOLE.	23rd foot.	24th foot.	25th foot.	26th foot.	27th foot.	28th foot.	29th foot.	30th foot.	31st foot.	32nd foot.	33rd foot.	34th foot.	35th foot.	36th foot.	37th foot.	38th foot.	39th foot.	40th foot.	41st foot.	Average.
Moisture	4·86	4·82	4·62	4·54	4·74	5·12	4·84	4·94	4·56	4·24	4·48	3·80	3·62	3·44	3·36	2·76	3·36	3·00	2·88	4·10
Volatile matter (exclusive of moisture).	24·78	25·74	24·82	25·66	26·36	25·94	25·56	25·94	24·44	29·64	23·24	27·44	24·24	23·48	22·80	21·20	21·92	21·54	20·06	24·46
Fixed carbon	30·30	30·92	28·92	30·24	30·98	33·22	30·46	29·12	26·36	20·46	24·68	28·00	22·82	22·42	23·32	22·12	24·12	22·90	21·68	26·49
Ash	40·06	38·52	41·64	39·56	37·92	35·72	39·14	40·00	44·64	45·66	47·60	40·76	49·32	50·66	50·52	53·92	50·60	52·56	55·38	44·95
TOTAL	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

N.B.—Does not cake. Ash, light grey.

Four bore holes were run down in this area, by which it was ascertained that there are two other seams, four in all, above those assayed; but they are thin and inferior in quality. The area containing these is very small, only about a square mile in extent; quite large enough however, had either of the thick seams been of any good, to have given a large amount of fuel.

The representatives of the same measures to the north of Tumidih, on the Nagoi side, are even poorer than those of the Pasaha *nala*, being merely a succession of grey and carbonaceous shales, with thin bands, or layers, of inferior coal; and this condition of affairs only agrees with what had already been observed for many miles to the north by Mr. Ball and myself. There was therefore really no use in wasting more time or money in this direction.

Korba, and its neighbourhood.—Two borings were started at Korba, on the river bank opposite the town; and a cross-cut was made in the great exposure or outcrop of shales and coal in the river bed. Two borings were likewise put down near Sumheda, or rather Ghordewa, on the Aharan river, near Hira Lal's outcrop,[1] into which a fresh cut was made.

Korba.—The cutting in the Hasdu was made in the most favourable-looking part of the outcrop, or about the middle, and gave us samples of 38 feet of the coal and shale. Thirty-five feet of this gave an average of 34·15 of ash. The best assays were:—

Number of feet.	Moisture.	Volatiles, exclusive of moisture.	Fixed carbon.	Ash.	Colour of ash.
1st	6·04	29·44	43·60	20·92	Brownish.
2nd	6·18	29·04	42·26	22·52	
16th	6·20	27·40	47·50	18·90	"
17th	5·64	26·44	40·76	27·16	
18th	4·44	31·90	43·10	20·56	
31st	7·44	26·40	45·32	20·84	"
37th	7·98	27·72	42·46	21·84	"
38th	8·64	27·00	45·64	18·72	"

It is very difficult, if not impossible, to compare the results in this cross-cut with those ascertained in 1870 during Mr. Blanford's examination,[2] for the latter was made by cuttings at good places throughout the whole measured outcrop, and it may be that Hira Lal did not touch on the 4 feet of good coal noted by Mr. Blanford, which gave the average:—

Carbon 57·5. Volatiles and moisture 25·2. Ash 17·3.

The lower two feet yielding—

Carbon 60·5. Volatiles and moisture 29·5. Ash 10·0.

But we can fall back on the boring, which, though not made in the bed of the river and thus in the coal outcrop, was nevertheless run down in the inland western

[1] Records, G. S. I., XIX, p. 223, 2nd para.
[2] Records, G. S. I., III, p. 54.

extensions of what appears to be the same seam through 69 feet of shale and coal, the thickness of the great seam at that point. Unfortunately there is no such good band of coal shown by the boring samples; all the coal is bad; and, again, a list of the samples recorded by us would be only a wearisome tale for tabulation or reading in the present paper. The average ash is 37·28 per cent.; and the only section of the bore hole worth looking at is as follows :—

No. of feet in seam.	Moisture.	Volatiles, exclusive of moisture.	Fixed carbon.	Ash.	Colour of the ash.
59th . .	5·92	28·36	37·40	28·32	Brown.
60th . . .	5·82	27·28	39·28	27·64	
61st . .	6·00	27·20	39·14	27·66	
62nd . .	5·12	24·56	42·32	28·00	

This 4-ft. band may answer to Mr. Blanford's band "*h*:" but in any case the whole series of assays from this boring go very much against the outcrop, while they again cast a cloud of doubt on the reliability of boring assays.

I examined all the country on the Korba side of the river and the outcrops in the Sitamanda and Kachendi streams, but without finding any improvement on the coal of the main outcrop.

Ghordewa.—Owing to lateness in the season we were only able to start two borings at this place, the first of which, at 429 feet from the outcrop and on the dip, went through the coal at 72 feet from surface (we had calculated on 70′—80′). The other boring No. 2 was estimated to cut the coal at 200 feet from the surface, but could only be carried down 153 feet. Here, for a wonder, the boring assays have not be-lied the promising outcrop to anything like the damaging extent exhibited in other parts of Chhattisgarh; but so remarkable an exception, for these fields, in the way of outcrop and boring assays must be well corroborated before venturing on colliery development.

The seam at the outcrop is 5 feet 3 inches thick; and the fresh cut made in it yielded assays as below :—

Analysis of Coal from the Outcrop in the Aharan between Sumedha and Ghordewa.

No. of feet.	Moisture.	Volatile matter, exclusive of moisture.	Fixed carbon.	Ash.	Colour of the ash.
1	8·80	25·80	57·42	7·98	Greyish.
2	5·56	17·58	48·96	27·90	"
3	7·78	28·84	55·74	8·02	"
4	8·40	28·28	56·36	6·96	"
5	8·32	30·58	52·42	8·68	"
Average excluding No. 2 .	8·32	28·37	55·48	7·91	...
Average of the whole seam .	7·77	22·21	54·18	11·90	...

On the other hand, the boring shows the coal to be somewhat thicker, six feet having been pierced; though this must be reduced a little on account of the dip The samples from it give the following results :—

Analysis of Coal from boring north of Ghordewa.

Number of feet from the surface.	Moisture.	Volatile matter, exclusive of moisture.	Fixed carbon.	Ash.	Colour of the ash.
72nd . .	5·28	28·20	52·30	14·22	Brown
73rd . .	5·52	29·76	52·14	12·58	
74th . .	5·22	27·06	52·92	14·80	
75th . .	5·16	27·58	53·96	13·30	
76th . .	5·34	27·80	54·70	12·16	
77th . .	5·20	21·08	39·34	34·38	
Average, excluding No. 77 . .	5·30	28·08	53·20	13·41	...

The lowest foot of the boring samples can only be called a shale, a condition to be reasonably expected in a coal seam, thus leaving nearly five feet of fairly good coal, as Indian coals go. A comparison with the outcrop assays will show, however, that even in so short a distance as 429 feet, the layers of the seam do not keep up uniformity, there being no bottom layer in the outcrop answering to the shale of the bore section; while the latter has no representative of the stony band (second foot from top) of the outcrop. All, then, that can be safely reckoned on is about 4 feet of coal throughout; say, in a circle whose diameter is 429 feet: it being quite possible, of course, that such a condition of affairs may exist far beyond so limited an area as this. Extended boring can only prove an extended area.

Résumé of experience gained.—I have now examined by boring, and I think sufficiently so, the separate areas in Hingir, Rampur, and the Baisandar valley, which have been grouped as—

A. Lillari valley,
B. Oira valley,
C. Baisandar valley,

under the one official heading of the Rampur coal-field.

The best seams of the Lillari valley borings gave average ash percentages at[1] :—

No. 1. Chowdibahal	44·18
No. 5. Kaliabahal	44·43
	40·23
No. 6. Bonjari	39·31

The Oira valley borings yielded coal carrying 42·71 per cent. of ash, or worse. The Baisandar valley gave no better assays: but here, for the first time, some doubt arose as to the possible unreliability of boring samples, owing to the difference observed between outcrop and bore samples.

No better results have been obtained from the latest borings in the Mand valley or from Korba itself.

[1] Records, G. S. I., XIX, 210.

On the boring assays alone, these coal-fields must be generally condemned as being unlikely to yield good workable and useful coal within the areas tried; and when I write "areas tried" I am practically condemning a very large extent of country indeed, in which, however, there is plenty of room for chance local developments that might pay private enterprise. Now, this, though a deliberate and sweeping condemnation, based on what has always hitherto been considered conclusive evidence, namely, the poorness of boring assays, does, on the face of it, seem too strong for so very great an area of coal-measures, carrying generally two very thick seams of shales and coal besides many other thin ones. Indeed, particularly so, when even the shadow of a doubt has been cast upon the reliability of the boring samples, and while such a promising local improvement shows itself at Ghordewa.

The chances that the boring samples have in some, if not many, cases been spoiled by admixture with foreign and deleterious débris of shales, and perhaps a little sand, are considerably reduced by our close and severe examinations of the Pasana outcrop and borings in the Mand valley; but they are not altogether eliminated, and, when the interests involved in the existence of coal in this part of the country are so great, it would, I think, be folly to leave the exploration in so unsatisfactory a state.

There is little use, however, in having more borings put down unless some more perfect apparatus and more skilled and reliable boring experts can be employed than have hitherto been available. The more immediately feasible plan is to have a small pit sunk on or near the site of some of the old borings in order that the seams they touched or ier ced should be tried in bulk.

The difficulty is to settle on a site, for I cannot point to one place as being preferable to another for its outcrops and bore samples. Such being the case, I fall back on a position as conveniently situated for railway purposes as possible. The Rampur coal-field has this advantage, and it is next nearest for possible supply to the Bengal fields, on the eastern side of the Peninsula. The boring assays from here give as much promise, bad as it is, as from anywhere else; the seams are of fair thickness, the depths at which they were encountered not being excessive; while the shortest distance from the proposed line of railway is only about 4 miles. By the journals or sections of No. 1[1] bore hole near Chowdibahal, a 7-ft. seam occurs at 77 feet from the surface, and there is another seam, 8 feet in thickness at 142 feet. This bore hole is at a good distance from the outcrop, so that there is no fear of any deterioration of the coal, such as, it may be, from proximity to weathering influences; and, as the depth is not excessive, a small pit might be run down on it. As the seams are reached, they should be well cut into, when the con ditions of their coal ought to settle the fate of the Rampur coal-field beyond dispute.

The next best situated place, though it be about 20 miles in a direct N.—S. line from the railway trace, is Korba: and it has these points about it, namely, that there is a great seam manifest to the eye of doubting and practical men of what looks like what ought to be coal, though it may have any amount of shale associated with it; and above all that so excellent an authority as Mr. W. T. Blanford did in the first instance report very favourably on it, and pointed out bands the better portions of which, from the evidence before him, he considered "equal in quality to

[1] Records, G. S. I., XIX, p. 226, and plate, fig. 1.

any coal found in the Ranigunj field." Of course, this opinion of Mr. Blanford was somewhat qualified by the assays received by him at a later date. A small trial pit could be easily run down here on the site of our boring to a total depth of 94 feet, which would pass through the entire seam and show in fair bulk the constitution of the many coal bands.

Local improvement.—That places of better promise may eventually be found is shown by the case near Ghordewa on the Aharan river, which is only about 5 miles west-north-west of Korba; but, as stated in the previous paper, to go on searching for such would be very much like looking for a needle in a bundle of hay. The Ghordewa case remains, however, and it certainly is promising enough to demand further exploration as to the extent and quality of its coal. The place is about 40 miles north-west of Bilaspur, and its shortest distance due south to the Bilaspur-Champa section of the Nagpore-Bengal Railway trace is about 25 miles: it is thus further from railway development than any other spot I have thought[1] worthy of examination, the Baisandar valley excepted. The great feature about it is that the outcrop gives the best 4 feet of coal known to exist in Chhattisgarh, and that the bore assays prove that it does not deteriorate to the deep. Hitherto, we have found such assays giving a decided and damnatory deterioration at only a few yards from the outcrop, but the assays in this case were made on material procured at 143 yards distance. The fear in my mind arising from what I have seen in many areas of these coal measures, in the case of a clean seam of coal—that is without much shale,—between thick beds of fine and uniform sandstones, is that the seam may not be very extensive: but this is no fair ground for deterring exploration. I think, on the whole, there is really more chance of finding by boring that the coal of the Ghordewa area shall continue as good and as thick over an area, say, of a couple of square miles, than that a pit shall show in any of the other localities that the coal is so much superior to the stuff brought up from the borings as to be extensively useful for railway consumption.

Note.—The Chhattisgarh coal-fields have, previous to this paper, been referred to in the following published accounts:—

W. T. BLANFORD.—*Report on the Coal at* Korba *in the* Bilaspur District. Records, G. S. I., III, p. 54.

" " *Note on the Occurrence of* Coal, east of Chhattisgarh *in the country between* Bilaspur *and* Ranchi. Records, G. S. I., III, p. 71.

V. BALL.—*The* Raigur *and* Hingir (Gangpur) Coal-field. Records, G. S. I., IV, p. 101.

" " *The* Raigarh *and* Hingir Coal-field. Records, G. S. I., VIII, p. 162.

" " *On the* Coal-bearing rocks *of the valleys of the upper* Rer *and the* Mand *Rivers in* Western Chutia Nagpur. Records, G. S. I., XV, p. 108.

W. KING.—*On the selection of* Sites *for* Borings *in the* Raigarh-Hingir Coal-field. Records, G. S. I., XVII, p. 123.

" " *Sketch of the Progress of Geological Work in the* Chhattisgarh Division *of the* Central Provinces. Records, G. S. I., XVIII, p. 169.

" " Boring Exploration *in the* Chhattisgarh Coal-fields. Records, G. S. I., XIX, p. 210.

[1] It may be mentioned that there is a very promising field in this same great area of coal-bearing rocks in the Uprora-Lakhanpur country, but this is too out of the way and difficult of approach for consideration in the present railway system. It is on the eastern extension of the Southern Rewa coal-fields.

Some remarks on Pressure Metamorphism *with reference to the Foliation of the* Himalayan Gneissose-Granite; *by* COLONEL C. A. MCMAHON, F.G.S.

A few years ago the theory found favour with some geologists that granite was the product of the extreme metamorphism of slate, sandstone, and other rocks of sedimentary origin, and that this metamorphism was the result of the heat developed by the compression of strata in the course of mountain formation. As there were serious chemical and other difficulties, however, in the way of the acceptance of this hypothesis, it gradually lost its hold on the geological mind, and another one, the converse of that above alluded to, now holds the field and seems likely to acquire especial prominence in the future in connection with the geology of the Scotch highlands.

The application of the first theory to the Dalhousie rocks I considered in my paper on the geology of that region (Records, XV, 39, 45, 46), and I came to the conclusion that the granitic structure of the gneissose-granite was not due to heat produced by pressure. The principal argument on which I relied was, shortly stated, as follows; if the heat which produced the granite structure were the product of local pressure, one would expect to find the greatest thickness of granite, and the most perfect granitic structure, developed at the point of greatest pressure; whereas, in the Dalhousie region, the contrary is the case, and at the point of greatest strain the gneissose-granite exhibits its minimum thickness and maximum amount of foliation.

In my previous papers, however, I did not consider whether the ascertained facts could be explained by the pressure metamorphism theory, and I now propose to offer a few remarks on this subject.

The pressure metamorphism hypothesis, shortly stated, may be said to consist of two parts. It is known as a fact that solid bodies such as lead, limestone, ice, &c., can, under the influence of great pressure, be made to flow; and from this fact the advocates of the pressure metamorphism hypothesis infer that many square miles of solid crystalline rocks have flowed with the plasticity of treacle under the influence of enormous pressure. This theory further supposes that when rocks are set in motion in this way the shear, and friction, develope sufficient heat to fuse, or dissolve, the minerals of which the rock is composed and that recombinations of the chemical constituents, and recrystallization, take place on cooling. This hypothesis, it will be observed, is a very comprehensive one and likely to be very useful to the puzzled geologist in the field. The conversion of a granite into a mica-schist can be accounted for by the application of the first part of the theory; whilst the conversion of a mica-schist into good granite can be explained by the second branch of the hypothesis.

I have no present wish to enter the lists against this theory, as a theory; indeed I have myself called in the aid of pressure to account for the foliation observed in the Sutlej diorites and lavas and the production of hornblende schists in that locality (Records, XIX, 80—83); all that I propose to do is to consider whether the facts ascertained regarding the gneissose-granite of the N. W. Himalayas, and recorded

in my previous papers, harmonize with the theory that the foliation of that rock was produced by pressure applied *after* its consolidation *as a granite.*

As I have discussed this question in an article on the gneissose-granite of the Himalayas recently published in the Geological Magazine (p. 212, May 1887), I think it will suffice to give an extract from this publication. It may be convenient to the future student of the Himalayan gneissose-granite to have his attention directed to this branch of the enquiry in connection with these papers—

"The cause, or causes, which result in the foliation of igneous rocks is a subject which at present occupies the attention of many geologists, and seems likely, in the near future, to lead to some discussion. In view of this, a short account of the foliated granite of the Himalayas may be of interest. It may be as well, however, to preface my remarks by saying that I believe that foliation may be produced in several distinct ways, and the explanation which I offer of the mode in which the foliation of the Himalayan granite has been brought about is only intended to apply to the case of that granite.

* * * * * *

"*Cause of the Foliation of the Gneissose Granite.*

"A realization of the eruptive character of the rock described in the above pages removes many difficulties from the way of the Himalayan geologist. "Despite the wonders performed by flexure of strata in mountain regions," wrote Mr. Medlicott, the Director of the Geological Survey of India, in his Annual Report for 1883, "the structural features presented by this rock in certain cases were impossible of satisfactory explanation on the supposition of its being a really stratified gneiss." But if the eruptive origin of the gneissose-granite be admitted, the further question arises whether the foliation observed in it was produced prior, or posterior, to the consolidation of the rock. In considering this question, I leave out of sight altogether evidence of fluxion structure as being really irrelevant to the question at issue, though I think it material to state that the rock does show very decided evidence of fluxion. Without laying any stress on this fact, however, I think the following considerations prove that the foliation was not produced by pressure acting on the rock after its consolidation.

"First, the granite is not always foliated at its contact with the rocks into which it has been intruded; on the contrary, though still porphyritic, it is not unfrequently decidedly granitic along its margin. This fact presents no difficulty to the acceptance of the hypothesis advocated below, but I think it offers an insuperable barrier to the acceptance of the view that the foliation was produced by pressure. Simple pressure will not do: that would not explain the crumpled micas and the very decided evidence of flow or fluxion. Pressure resulting in shear motion, the development of heat and concomitant chemical and mineralogical action, might possibly account for the fluxion structure; but if shear and motion were established on the grand scale required after the consolidation of the rock, the granitic portions along the margins could not possibly have escaped the effects of this action.

"Secondly, the apparently capricious passage from a granitic to a foliated structure in the main mass of the granite is another serious impediment in the way of the acceptance of the theory of dry pressure.[1]

"Thirdly, the conjunction of the outer band of gneissose granite at Dalhousie with the carboniferous series presents another almost insuperable difficulty. The outer band is the most intensely foliated of all the Dalhousie granite. Parts of it look as if it had been rolled under a gigantic steam roller. Unquestionably it has been subjected to very great pressure, and to either traction or shearing; and yet this rock is chock and block with little altered black carboniferous rocks. He who would apply the dry-pressure theory to explain the intense foliation of the outer band of granite, would have to invent a new set of conditions out of his inner consciousness and bring some other rock into position next the granite before he applied the squeeze.

[1] I use this expression as a short term to indicate pressure applied *after* the consolidation of a rock, though of course, I am aware that pressure so applied may produce heat and even fusion.

"Fourthly, the condition of the long tent-peg-like splinter of schist included in the granite, alluded to above,[1] shows conclusively that the granite at the point where the inclusion was found was not subjected to extreme pressure of the character under consideration after its consolidation. Had it been, the splinter of schist would have been flattened to a wafer. A mere glance at the plate, a photograph reproduced by the heliogravure process, will show this at once.

"Fifthly, neither the crypto-crystalline mica, nor the fish-roe quartz, described *ante*, can possibly have been produced by the grinding down of the mica and the quartz in the consolidated rock, or by any analogous process; for, besides the crypto-crystalline mica, and the fish-roe quartz, we have very numerous *large* crystals of muscovite, biotite, and quartz. The muscovite and biotite are large and beautiful specimens of these minerals, and they orient in all directions and at every angle up to a right angle to the strings of crypto-crystalline mica. Mechanical action potent enough to have reduced mica to the pulpy condition of the crypto-crystalline mica would not have left the larger micas untouched. Similarly, the fish-roe quartz not only fills cracks in felspars, and forms a sort of setting to quartz grains, but it meanders about in the interior of large quartz grains, and terminates abruptly inside them, in a way that does not suggest to the observer that he is looking at cracks stopped with micro-crystalline quartz, but rather that the crystallization of the quartz was brought to a comparatively rapid termination towards its close.

"Indeed, properly considered, I think the crypto-crystalline mica, and the fish-roe quartz, furnish a clue to the riddle. I may mention in passing that I have observed in a felsite patches of material closely resembling the crypto-crystalline mica mixed up with the quartz and the ordinary felsitic base; but I desire more particularly to refer to a series of rocks which occur in the peninsula of India about eighty-five miles nearly due west of Delhi. We have there a very interesting group ranging from felsites, quartz-porphyries, and granite-porphyries to almost true granites. The felsites appear to be true lavas; and the others, though merging gradually into rocks of plutonic character, are probably more or less directly connected with them. These rocks never show any trace of foliation, or give any indication of crushing. But what is important to note is, that the gradual genesis, so to speak, of the fish-roe quartz may be observed in these rocks. The quartz gradually becomes more and more developed in the felsitic base; it begins to crystallize out in grains of microscopic size, and the grains increase in number, until at last the whole base, or ground-mass, of the granite-porphyries partakes closely of the characters of the fish-roe quartz of the Dalhousie granite. The true explanation of the foliation of the latter rock I believe to be briefly as follows:—The rock had partially consolidated before it was moved into place; large porphyritic crystals of felspar, and numerous micas and quartz grains had formed; it was very much in the condition of a felspar-porphyry, or a granite-porphyry; when, in the course of the earth-movements that were contorting, crumpling, and folding the strata of the Himalayas, this imperfectly consolidated granite-porphyry was forced through the faults that had been formed along the axes of over thrust-folds; the semi-plastic mass was subjected to enormous pressure; the mica was crumpled; the crystals of felspar were cracked and ruptured; and so much of the micaceous siliceous materials as remained unconsolidated were forced into the rents made in the already formed minerals. The final consolidation took place under conditions of continued strain; but before it was actually accomplished minor and subsidiary eruptions took place which forced new supplies of the granitic material into fissures formed in the previously injected rock, and this fresh material consolidated under conditions somewhat different from those of the first eruptions.

"I think this view meets all the difficulties of the case, and that the intelligent reader will with its aid be able to harmonize all the facts stated above without detailed exposition on my part."

[1] See Records G. S. XVII, p. 168.

A list *and* index *of papers on* Himalayan Geology *and* Microscopic Petrology, *by* COLONEL C. A. MCMAHON, F.G.S., *published in the preceding volumes of the Records of the Geological Survey of India.*

LIST OF PAPERS.

INDEX.

ADDITIONS TO THE MUSEUM.

FROM 1ST OCTOBER TO 31ST DECEMBER 1886.

A series of 16 specimens in mahogany case, illustrating the extraction of copper from cupreous pyrites.
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Soondri wood from 15 to 18 feet below surface and 4 feet above zero of tidal gauge, near Diamond Harbour Telegraph Station.

PRESENTED BY MR. S. R. ELSON.

Tooth of *Euelephas indicus* from a skull found at a depth of 24 feet in the delta of the Godavari, at Dowlaishweram.

PRESENTED BY MR. T. VANSTAVERN.

Nine fragments of pebbles with *Conularia*, from the palæozoic boulder bed in the Nilawan, Salt-Range.

PRESENTED BY DR. H. WARTH.

Five specimens of fossil plants from the Iron-stone measures, Barakar.

PRESENTED BY C. RITTER VON SCHWARZ.

Turquoise from Los Cerillos, New Mexico; and Native Antimony from Prince William York Co., New Brunswick.

PRESENTED BY MR. G. F. KUNZ.

Three specimens of jadeite and two of omphacite ?, from Upper Burma.

PRESENTED BY DR. R. ROMANIS.

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PRESENTED BY MR. K. SUMITOMO, OSAKA.

Calcareous aggregation upon an old anchor found at a depth of 4 fathoms in Colombo harbour, November 3rd 1886. (Illustrating the formation of shell limestone).

PRESENTED BY MR. F. J. DALEY. (?)

Specimens of rock crystal; beryl, in quartz; beryl, with mica in quartz; garnet, in mica schist; and garnets, from different localities in Jaipur.

PRESENTED BY THE HONORARY SECRETARY, JAIPUR MUSEUM.

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July 13th, 1887.

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Five specimens of jade, from the jade quarries, Burma.

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A piece of amber containing insects, from Palmnicken, near Königsberg, East Prussia.

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